

***Astragalus barrii* Barneby (Barr's milkvetch):  
A Technical Conservation Assessment**

**Prepared for the USDA Forest Service,  
Rocky Mountain Region,  
Species Conservation Project**

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# SUMMARY OF KEY COMPONENTS FOR CONSERVATION OF *ASTRAGALUS BARRII*

## *Status*

*Astragalus barrii* (Barr's milkvetch) is ranked globally vulnerable, G3, by NatureServe, and vulnerable (S3) at the state level by the Wyoming Natural Diversity Database, the South Dakota Natural Heritage Program, and the Montana Natural Heritage Program. It is ranked critically imperiled (S1) by the Nebraska Natural Heritage Program. *Astragalus barrii* is designated a sensitive species by USDA Forest Service (USFS) Region 2, USFS Region 1, and a Watch species by the USDI Bureau of Land Management (BLM) in Montana.

## *Primary Threats*

Activities associated with natural resource development, particularly of coal bed methane gas, are emerging as the primary potential threats to the habitat of *Astragalus barrii* in the Powder River Basin of Wyoming and Montana. Range-wide, some populations have been impacted by resource extraction activities in the past, but the impacts appear to have been localized. Badlands are popular off-road vehicle (ORV) recreation areas, and recreational ORV use of habitat poses a significant threat to some populations. In particular, it poses a threat to a population within the Railroad Butte area that experiences a high amount of recreational vehicle use. The Railroad Butte area is in South Dakota and is managed by USFS Region 2. As the human population grows in areas within easy access to *A. barrii* habitat and as recreational use increases, the impacts may become substantially more significant in all areas where it occurs. Land exchanges between the USFS and private landowners to consolidate holdings might threaten some occurrences or potential habitat on National Forest System lands. Alternatively, the exchanges might benefit occurrences and potential habitat that were on private lands prior to the exchange. The consequences of urbanization may impact some populations, especially in areas that are undergoing an influx of people due to coal bed methane development. Potentially, the Dakota Minnesota and Eastern Railroad, which will traverse both the Thunder Basin National Grassland and the Buffalo Gap National Grassland, could impact some *A. barrii* occurrences. At current levels, grazing and trampling by native and non-native ungulates may have an impact on some of the smaller colonies but do not appear to substantially threaten any of the larger known populations. Invasive noxious weeds and the proliferation of aggressive non-natives are likely a threat to long-term sustainability of some populations due to habitat degradation and competition.

## *Primary Conservation Elements, Management Implications and Considerations*

*Astragalus barrii* is a rare species endemic to the badlands of southwestern South Dakota, far northwestern Nebraska, and the Powder River Basin of Wyoming and Montana. It is restricted to areas with low vegetation cover, suggesting that it is unable to compete with invasive plant species. Apparently it can persist in or re-colonize areas after vehicle or animal disturbance although the sustainability of populations at high disturbance sites is unknown. The information currently available suggests that some populations are relatively secure because they occur in areas that are afforded protection by land use designation, for example a national park. It is afforded no conservation consideration on BLM public lands in Wyoming where development of natural resources, such as oil, gas and coal bed methane, is currently being aggressively pursued. Because of the potential degradation of habitat in much of its range, populations in areas such as South Dakota that are not subject to exploitation may assume conservation value importance in the future. There are no documented management plans or conservation strategies directly concerning *A. barrii*. However, the Northern Great Plains Management Plans of USFS Region 2 have specifically addressed general management issues of this taxon. The Dakota Minnesota and Eastern Railroad Draft Environmental Impact Statement mentioned that potential impacts to *A. barrii* would be examined by the USFS, BLM, and botanical experts. Because of the cryptic nature of vegetative plants and the similarity between *A. barrii* and sympatric taxa, it is important that surveys be carried out when the plant is flowering. The observation that most individuals appear long-lived suggests that persistence in adult form is critically important to the life history of the taxon. In order to promote proactive steps towards threat mitigation, more information is needed on the impact of human-caused disturbances, such as vehicle traffic, on the long-term response of *A. barrii* individuals and populations. This information can be obtained through long-term monitoring studies. An important detail to remember is that several statements that have been reported

concerning the response of *A. barrii* to land use practices, in particular its tolerance to disturbance, are derived from relatively casual observations, and no long-term studies have been made to rigorously validate the observations. *Astragalus barrii* is known from approximately 46 occurrences in Wyoming, approximately 27 occurrences in South Dakota, and approximately 35 occurrences in Montana. There are less than three occurrences in northwestern Nebraska, none of which are on National Forest System land.

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## INTRODUCTION

This assessment is one of many being produced to support the Species Conservation Project for the Rocky Mountain Region (Region 2) USDA Forest Service (USFS). *Astragalus barrii* Barneby (Barr's milkvetch) is the focus of an assessment because it is designated as sensitive in Region 2 (USDA Forest Service 2005). Within the National Forest System, a sensitive species is a plant or animal species whose population viability is identified as a concern by a Regional Forester because of significant current or predicted downward trends in abundance and/or in habitat capability that would reduce its distribution (USDA Forest Service 1994). A sensitive species may require special management, so knowledge of its biology and ecology is critical.

This assessment addresses the biology of *Astragalus barrii* (Barr's milkvetch) throughout its range. The broad nature of the assessment leads to some constraints on the specificity of information for particular locales. This introduction defines the goal of the assessment, outlines its scope, and describes the process used in its production.

### *Goal*

Technical conservation assessments produced as part of the Species Conservation Project are designed to provide forest managers, research biologists, and the public with a thorough discussion of the biology, ecology, and conservation status of certain species based on scientific knowledge accumulated prior to initiating the assessment. The assessment goals limit the scope of the work to critical summaries of scientific knowledge, discussion of broad implications of that knowledge, and outlines of information needs. The assessment does not seek to develop specific management recommendations. Rather, it provides the ecological background upon which management must be based and focuses on the consequences of changes in the environment that result from management (i.e., management implications). Furthermore, it cites management recommendations proposed elsewhere and examines the success of those recommendations that have been implemented.

### *Scope*

This assessment examines the biology, ecology, conservation status, and management of *Astragalus barrii* with specific reference to the geographic and ecological characteristics of USFS Region 2. Although some of the literature relevant to the species may originate from field investigations outside the region,

this document places that literature in the ecological and social context of lands managed by the Region 2 USDA Forest Service. Similarly, this assessment is concerned with reproductive behavior, population dynamics, and other characteristics of *A. barrii* in the context of the current environment rather than under historical conditions. The evolutionary environment of the species is considered in conducting this synthesis, but placed in a current context.

In producing the assessment, refereed (peer-reviewed) literature, non-refereed (not peer-reviewed) publications, research reports, and data accumulated by resource management agencies were reviewed. Not all publications on *Astragalus barrii* may have been referenced in this assessment, but an effort was made to consider all relevant documents. Refereed literature is preferred because it is the accepted standard in science. While in some cases non-refereed publications and reports may be regarded with greater skepticism, they were sometimes used in the assessment because information was unavailable elsewhere. Many reports or non-refereed publications on rare plants are often 'works-in-progress' or isolated observations on phenology or reproductive biology. For example, demographic data may have been obtained during only one year when monitoring plots were first established. Insufficient funding or staffing may have prevented work in subsequent years. One year of data is generally considered inadequate for publication in a refereed journal but still provides a valuable contribution to the knowledge base of a rare plant species. Unpublished data (for example, Natural Heritage Program and herbarium records) were important in estimating the geographic distribution and population sizes of this species. These data required special attention because of the diversity of persons and methods used in collection. Records that were associated with locations at which herbarium specimens had been collected at some point in time were weighted higher than observations only.

### *Treatment of Uncertainty*

Although *Astragalus barrii* has been known for almost 50 years, the information on which to base an assessment is incomplete. Generally, science represents a rigorous, systematic approach to obtaining knowledge. Competing ideas regarding how the world works are measured against observations. However, because our descriptions of the world are always incomplete and observations limited, science focuses on approaches for dealing with uncertainty. A commonly accepted approach to science is based on a progression of critical experiments to develop strong inference

(Platt 1964). However, strong inference as described by Platt, suggests that experiments will produce clean results (Hillborn and Mangel 1997), as may be observed in certain physical sciences. The geologist, T.C. Chamberlain (1897) suggested an alternative approach to science where multiple competing hypotheses are confronted with observation and data. Sorting among alternatives may be accomplished using a variety of scientific tools (experiments, modeling, logical inference). Statistics, used in experiments and quantitative observation, is a powerful tool to address uncertainty in ecology and systematics. Ecological science is, in some ways, more similar to geology than physics because of the difficulty in conducting critical experiments and the reliance on observation, inference, logical thinking, and models to guide understanding of the world (Hillborn and Mangel 1997).

Confronting uncertainty, then, is not prescriptive. In this assessment, the strength of evidence for particular ideas is noted, and alternative explanations are described when appropriate. While well-executed experiments represent a strong approach to developing knowledge, alternative approaches such as modeling, critical assessment of observations, and inference are accepted approaches to understanding. For this particular species of *Astragalus*, an example of an element of uncertainty is species identification. From a distance and in the vegetative state (i.e., in the absence of flowers), this taxon can easily be confused with sympatric taxa. Another element of uncertainty is generated from imprecise knowledge of its habitat requirements and response to disturbance. The reasons why it is very abundant in localized areas are currently unknown.

### ***Publication of the Assessment on the World Wide Web***

To facilitate use of species assessments in the Species Conservation Project, they are being published on the Region 2 World Wide Web site. Placing the documents on the Web makes them available to agency biologists and the public more rapidly than publishing them as reports. More importantly, Web publication will facilitate revision of the assessments, which will be accomplished based on guidelines established by Region 2.

### ***Peer Review***

Assessments developed for the Species Conservation Project have been peer reviewed prior to release on the Web. This report was reviewed through a process administered by the Center for Plant Conservation, employing two recognized experts on this or related taxa. Peer review was designed to improve the quality of communication and to increase the rigor of the assessment.

## **MANAGEMENT STATUS AND NATURAL HISTORY**

### ***Management Status***

*Astragalus barrii* has no federal legal status at the present time. It was proposed as a Category 2 species, or Candidate for listing, under the Endangered Species Act of 1973 by the USDI Fish and Wildlife Service (1985). Category 2 taxa included species that might have warranted listing as Threatened or Endangered, but for which the USDI Fish and Wildlife Service (USFWS) lacked sufficient biological data to support a listing proposal. In 1993, the USFWS revised the designation of *A. barrii* to Category 3-C. Species listed as Category 3-C were defined as “taxa that have proven to be more abundant or widespread than previously believed and/or those that are not subject to any identifiable threat, but remain under research and may be reevaluated” (USDI Fish and Wildlife Service 1993). In 1996, the USFWS discontinued designating species beyond those that are actually listed as Threatened or Endangered or those that are primary candidates for listing. The USFWS now relies on other information sources, such as lists of rare and endangered species developed by programs within individual states and the NatureServe Database System, to identify those species that may be vulnerable.

The NatureServe Global<sup>1</sup> rank for *Astragalus barrii* is vulnerable, G3 (see Ranks in the **Definitions** section; NatureServe 2003). It is also designated vulnerable, S3, by the Wyoming Natural Diversity Database (2005), the South Dakota Natural Heritage Program (NatureServe 2005), and the Montana Natural Heritage Program (2005a). It is ranked critically imperiled (S1) in Nebraska (NatureServe 2005).

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<sup>1</sup>For definitions of “G” and “S” ranking, see Ranks in the **Definitions** section at the end of this document.

*Astragalus barrii* is designated a sensitive species by both Region 1 and Region 2 of the USFS (USDA Forest Service 2005). It is designated a Watch species by the USDI BLM in Montana. A Watch species is “any species either known to be imperiled and suspected to occur on BLM managed public lands; suspected to be imperiled and documented on BLM lands; or needing further study for other reasons” (USDI Bureau of Land Management 6840 Manual; see Montana Natural Heritage Program 2005b).

Recently, BLM Wyoming Field Office biologists requested that *Astragalus barrii* be designated a sensitive species in accordance with BLM Manual 6840 - Special Status Species Management (USDI Bureau of Land Management 2003a). It was not added to the list because it was determined that *A. barrii* did not meet the “sensitive species criteria and policy” (USDI Bureau of Land Management 2003a). There was no further explanation or information given regarding this decision.

### ***Existing Regulatory Mechanisms, Management Plans, and Conservation Strategies***

*Astragalus barrii* occurs on land managed by the USFS and the BLM, on state land, and on private land in Wyoming, Montana, and South Dakota. In Nebraska, it has only been found on private land. In South Dakota, it also occurs on Native American tribal lands and on land managed by the National Park Service.

Most land on which *Astragalus barrii* occurs is managed for multiple uses. An exception is land managed by the National Park Service. The National Park Service manages national parks “...to promote and regulate the use of the...national parks...which purpose is to conserve the scenery and the natural and historic objects and the wild life therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations” (National Park Service Organic Act, 16 U.S.C.1). Logging, mining, and other activities to exploit natural resources are usually prohibited (Environmental Media Services 2001). With support from the National Park Service, a predictive model of the habitat of *A. barrii* in South Dakota has been developed (Dingman 2004, Dingman 2005). This may aid in predicting potential habit, at least in South Dakota, when evaluating development permit requests on federally managed land (Boetsch et al. 2003, Carroll personal communication 2003).

One of the regions where *Astragalus barrii* is locally common is in the Powder River Basin. This region includes the Custer National Forest and at least 90 percent of the Thunder Basin National Grassland (Taber and Kenney 1999, EPCA Interagency Team 2000, USDA Forest Service undated). In the Final Environmental Impact Statement for the Land and Resource Management Plan of the Thunder Basin National Grassland, Region 2, it was noted that none of the existing populations of *A. barrii* occur within Management Area 8.4, which encompasses mineral production and development (USDA Forest Service 2001c). However, there are some occurrences that appear to be within the sphere of influence of mineral and resource development (USDI Bureau of Land Management 2003b). *Astragalus barrii* has been reported as being likely to occur in the Rock Creek Research Natural Area (RNA) managed by the Thunder Basin National Grassland, Region 2 (USDA Forest Service 2001b). However, there are no documented occurrences actually within the RNA at the current time. One of the objectives in conveying RNA status is to protect the elements of biological diversity for which the RNA is established (USDA Forest Service 1995). The Rock Creek RNA is valued because it includes rolling hills with alluvial soils that support vegetation of the big sagebrush/needle-and-thread, the needle-and-thread/blue grama, and the silver sagebrush/western wheatgrass plant associations (USDA Forest Service 2001b). These communities and soils may provide habitat for *A. barrii*, and therefore the RNA will be managed to maintain habitat for *A. barrii*.

Within the last fifteen years, several surveys have been made for *Astragalus barrii* in order to define its distribution and abundance. Within Region 2, surveys have been made specifically for *A. barrii* within the Buffalo Gap National Grassland, including Linaberry (1991), Muenchau et al. (1991a, 1991b), Hoy et al. (1993a), and Schmoller (1993), and on the Thunder Basin National Grassland (Heidel 2004). The survey in 2003 on the Thunder Basin National Grassland in the Spring Creek Unit was conducted primarily to familiarize USFS personnel with the species and appropriate survey techniques. The surveys were developed using photo-interpretation and ground-truthing (Heidel 2004). A collaborative effort between several institutions and the USFS is being made to model and map habitat for *A. barrii* in Wyoming (Roche personal communication 2005). Marriott (1992) made a survey on BLM land in Wyoming. Several surveys specifically for *A. barrii* have been made within the last two decades in Montana. They include Schassberger

(1988, 1990), Schmoller (1995), Heidel and Marriott (1996), Heidel et al. (2002), Taylor and Caners (2002), and Barton and Crispin (2003). Several of those surveys included land managed by the Custer National Forest (Region 1) and the BLM. All of these surveys have significantly contributed to the current knowledge on *A. barrii*.

The Center for Plant Conservation (CPC) has formed a network of institutions to collect seed and propagate plant taxa that are considered to be of conservation concern (Center for Plant Conservation 2004). As a participating institution with the CPC network, the CPC National Office at the Missouri Botanical Garden in St. Louis, Missouri is maintaining *Astragalus barrii* (Center for Plant Conservation 2005).

## ***Biology and Ecology***

### **Classification and description**

#### ***Systematics and synonymy***

The genus *Astragalus* belongs to the Fabaceae or Leguminosae family, commonly known as the pea family. Members of the genus *Astragalus* are known from North and South America, Europe, Asia, India, and Africa. It is an extremely variable genus both in morphology and habitat requirements, with approximately 1,500 to 2,000 species worldwide (Isely 1998). North America is particularly rich in *Astragalus* species.

*Astragalus barrii* belongs to the *Sericoleuci* section of the *Orophaca* phalanx of the genus *Astragalus* (Barneby 1964). Nathaniel L. Britton (1897) described a group of dwarf, matted *astragali* that had palmately trifoliate leaves and dolabriform hairs and assigned them to the genus *Orophaca*. In Barneby's extensive treatment of North American *astragali*, all of these palmately trifoliate leaved *astragali* remained in the genus *Astragalus* (Barneby 1964). More recently, Isely (1983, 1998) again suggested that it was most appropriate to segregate members of the *Orophaca* from the genus *Astragalus* in accordance with what Britton (1897) had advocated. Therefore, a synonym of *A. barrii* is *O. barrii* (Barneby) Isely. Isely (1983, 1998) argues that the *Orophaca* represents a compact group of eight species that are clearly distinguishable by their palmately trifoliate leaves. In addition, he commented that they are clearly separable from all old world *astragali* by having a base chromosome number of 12, unlike the old world *astragali* base number of 8 (Spellenberg 1976, Isely 1998). Floras relevant

to Region 2 may or may not recognize *Orophaca* as distinct from *Astragalus*. Weber and Wittmann (2001) accept *Orophaca*; Dorn (1984, 1988, 2001) and Great Plains Flora Association (1986) include the orophacoid *astragali* in *Astragalus*, considering *Orophaca* to be a synonym.

Some consider that the position of *Orophaca* has still to be resolved. Considering the conventions of phylogenetic classification and based on the nucleotide sequence variation in the internal transcribed spacer (ITS) regions of nuclear ribosomal DNA from *Astragalus aretioides* (phalanx *Orophaca*, section *Sericoleuci*), Sanderson and Liston (1995) suggested that one conservative option is to keep the genus *Astragalus* with *Orophaca* as a subgenus.

Barneby (1956) reported that *Astragalus barrii* is closely related to *A. tridactylus*, which is also in the section *Sericoleuci*. Like *A. barrii*, *A. tridactylus* grows on poorly developed soils in relatively open sites in xerophytic habitats (Vestal 1914, Roberts 1977). However, the two species are both morphologically and geographically sharply separate (Barneby 1956). Roberts (1977) also noted that *A. barrii* resembled *A. gilviflorus*, which is also in the *Orophaca* phalanx but in the section *Orophaca* Barneby (Barneby 1964, Hu et al. 1999).

#### ***History of the species***

*Astragalus barrii* appears to have first been collected in 1900 in Wyoming, in 1932 in South Dakota (Ode 1990), and not until much later in Montana (**Table 1**). It was not described as a distinct species until 1956, at which time the epithet *barrii* was chosen to honor Claude A. Barr who studied the prairie flora and cultivated many taxa in his nursery at the Prairie Gem Ranch, Smithwick, South Dakota (Barneby 1956). Earlier Barr (1951) reported on several members of the *Orophaca*. In that article, he describes a population of *A. tridactylus*, which Barneby (1956) later determined to be the distinct taxon, *A. barrii*. Barneby (1964) designated the earliest collection, made by Frank Tweedy in 1900, a 'representative collection' of *A. barrii*. In some treatments, *A. barrii* is accepted as *O. barrii* (see Systematics and synonymy section).

#### ***Non-technical description***

*Astragalus barrii* is a low growing, densely tufted or mounded perennial that becomes cushion-like and elevated above the soil surface in eroding habitats. Barr (1951) graphically described the members of the

**Table 1.** Summary information for all known occurrences of *Astragalus barrii*. Included here are county, management, observation dates, location, habitat, abundance, distribution, and source information.

State-Arbitrary #	County	Management	Observation dates	Location	Habitat summary	Abundance/spatial distribution/Comments	Source <sup>1</sup>
WY-1	Natrona	Not reported	24-May-1998	Upper North Platte and Laramie River Drainages; Emigrant Gap Ridge approximately 14.8 miles west-northwest of Casper.	“Barren, saline ridge with scattered <i>Artemisia pedatifida</i> .”	No information.	A.J. Roderick 3921 RM
WY-2	Natrona	USDI Bureau of Land Management (BLM) - Casper Field Office	18-May-1991	Along a low ridge approximately 1.5 miles south-south east of Bucknum in the Powder River Basin.	“Ridgecrest and slopes to north on sandy-silty soil.” “With <i>Artemisia pedatifida</i> , <i>Agropyron spicatum</i> , and <i>Phlox hoodii</i> .”	“Estimated 500-1,000 individuals in the limited area surveyed.” “Locally common, estimated 10% in flower, remainder vegetative.” Powerline goes through population.	Wyoming Natural Diversity Database (2003)
WY-3	Niobrara	BLM - Newcastle Field Office	10-Jul-1979	Powder River Basin; approximately 8 miles northwest of Lance Creek.	Sandy plains, deep draws, sandstone outcrops - plains.	No information.	K.H. Dueholm 7949 RM and NY; Wyoming Natural Diversity Database (2003)
WY-4	Natrona	BLM - Casper Field Office	18-May-1991, 15-Jun-1993	Powder River Basin northwest of Casper, just south of Divide Road; on ridge west of Hemingway Draw and on knoll south of North Fork of Casper Creek; over three sections; sub populations not revisited.	1991: Specifically one sub-population: is on “upper southeast-north slopes of knoll on sandy silty soil.” Plants also on “ridgelets running mainly southwest from mainridge (roadway), on sandy-silty soil.” With <i>Artemisia tridentata</i> and <i>Agropyron spicatum</i> or <i>Artemisia pedatifida</i> and <i>Agropyron spicatum</i> . 1993: “Rolling plains with a mosaic of grassland, sagebrush-grassland, and semi-barren clay knolls, ridges, and slopes” (additional subpopulation).	1991: One sub-occurrence estimated 200 to 500 individuals; estimated 25 percent in bud/flower, remainder vegetative. Another sub-occurrence estimated 500 to 1,000 individuals in limited area surveyed (near road); estimated 20 percent in bud/flower, remainder vegetative.	Wyoming Natural Diversity Database (2003)
WY-5	Natrona	BLM - Casper Field Office	12-Jun-1985	Approximately 29 miles northwest of Casper in Southern Powder River Basin; was likely revisited in May 1991 but information unclear.	On “east-west divide, with gently sloping, shaley plains, steep, eroded, shaley north-facing slope of divide, small flat-topped butte, and drainages on slope and shallow drainage on plains; slopes.” and “Plains. Sandy.”	In fruit. No information.	K.H. Dueholm 11937 RM, NY; Wyoming Natural Diversity Database (2003)

Table 1 (cont.).

State-Arbitrary #	County	Management	Observation dates	Location	Habitat summary	Abundance/spatial distribution/Comments	Source <sup>1</sup>
WY-6	Natrona	BLM and/or private	23-May-1994	Notches Dome in Southern Powder River Basin.	On "steep soft clay cobblestone hills with scattered sagebrush, greasewood, and bluebunch wheatgrass."	No information.	B.E. Nelson 30564 RM
WY-7	Converse	State of Wyoming	2-Jun-2003	Approximately 1 to 1.5 miles southeast of Middle Creek Reservoir on the Western High Plains.	"Area is a transition from sagebrush grassland to creek. There is a slumping (slight increase in slope and erosion) of grassland before a drop to the riparian area."	100 to 300 estimated, probably more, with the majority in vegetative condition.	P. Ebertowski RM; Wyoming Natural Diversity Database (2003)
WY-8	Natrona	BLM - Casper Field Office; State of Wyoming	10-Jun-1985, 17-May-1991	Powder River Basin approximately 29 miles northwest of Casper near 33-mile Road; over 3 contiguous sections.	1985: "Broad shaley loam ridge and drainages." On "ridgecrests and slopes on pale, sandy-silty soil." 1991: With <i>Artemisia pedatifida</i> , <i>Agropyron spicatum</i> , and <i>Phlox hoodii</i> .	1991: Estimated 3,000 to 10,000 individuals in area surveyed. Scattered individuals or locally abundant. Estimated 90 percent in bud/flower in some areas, 90 percent vegetative in others.	K.H. Dueholm 11918 1985 RM; Wyoming Natural Diversity Database (2003)
WY-9	Niobrara	Unknown	13-Jun-1991	North of Prairie Center and south of Van Tassell.	No information.	No information.	Wyoming Natural Diversity Database (2003)
WY-10	Natrona	BLM - Casper Field Office	28-Jun-1986	Powder River Basin, near Castle Creek approximately 8 miles southwest of Edgerton.	Clay slopes. Occurs with <i>Artemisia pedatifida</i> and <i>Atriplex</i> spp.	No information.	R.D. Dorn 4343 RM; Wyoming Natural Diversity Database (2003)
WY-11	Converse	USFS Region 2 - Thunder Basin National Grassland, and/or private land	20-May-1976	In vicinity of Antelope Creek and Dull Center Road west of Dull Center.	No information.	No information.	J.F. Thilenius 28 RM
WY-12	Converse	USFS Region 2 - Thunder Basin National Grassland, and/or State land and/or private land	23-Aug-1999	Approximately 14 miles north-northwest of Bill; Sand Creek vicinity.	On "clay bank with <i>Haplopappus nuttallii</i> and <i>Phlox hoodii</i> ."	No information.	R. Dorn 8080 RM

Table 1 (cont.).

State-Arbitrary #	County	Management	Observation dates	Location	Habitat summary	Abundance/spatial distribution/Comments	Source <sup>1</sup>
WY-13	Converse	USFS Region 2 - Thunder Basin National Grassland	2-Jun-2003	Western High Plains northeast of Bill near the National Grassland boundary.	On "gentle sloping grassland, primarily facing east on clay to silty clay soil."	"Roughly 1,000 + individuals, likely several thousands." Estimate includes those seen on private land from road and from Forest Service Land.	P. Ebertowski RM; Wyoming Natural Diversity Database (2003)
WY-14	Natrona	BLM - Casper Field Office	17-May-1993	Southern Powder River Basin n the Casper Arch Region; approximately 3 miles north of Midwest.	"Just back or below sandstone rimrock."	No information.	B.E. Nelson 24775b RM; Wyoming Natural Diversity Database (2003)
WY-15	Natrona	BLM - Casper Field Office; State of Wyoming	18-May-1991	Powder River Basin approximately 3.5 miles west-northwest of Midwest.	"On crest of small ridge off main ridge, on sandy silty soil." With <i>Artemisia pedatifida</i> and <i>Agropyron smithii</i> .	Estimated 200 to 500 individuals; locally abundant; estimated 90 percent in bud/flower, remainder vegetative.	Wyoming Natural Diversity Database (2003)
WY-16	Natrona	BLM - Buffalo Field Office	17-May-1993	Southern Powder River Basin approximately 8.8 miles west of Midwest along Government Creek.	In "sagebrush-grassland interspersed with areas of <i>Artemisia pedatifida</i> and <i>Agropyron smithii</i> ."	No information.	B.E. Nelson 24823 RM; Wyoming Natural Diversity Database (2003)
WY-17	Weston	BLM - Newcastle Field Office	24-May-1991	Eastern plains, just north of the Cheyenne River; approximately 5 miles west of the Wyoming/South Dakota border at northwest end of Twentyone Divide; in small breaks off northeast side of Divide; over two contiguous sections.	"Sandy-silty soil at the heads of small breaks off the northeast side of Divide." With <i>Artemisia tridentata</i> and <i>Agropyron smithii</i> .	Estimated 200 to 500 individuals in area surveyed. Estimated 75 percent in bud/flower, remainder vegetative.	Wyoming Natural Diversity Database (2003); Marriott (1992)
WY-18	Weston	BLM - Newcastle Field Office	18-May-1976, 24-May-1993	Eastern plains, along Lone Tree Creek off the Morrissey Road just west of US Highway 85; approximately 23 mi south of Newcastle. Also included in this EO is a 1976 collection in the general area - "northwest of Rattlesnake Ridge and south-southeast of Newcastle."	Sagebrush-grassland with sparsely vegetated knolls.	1976: "Occasional."	B.E. Nelson 25183 RM 1993; Wyoming Natural Diversity Database (2003)

Table 1 (cont.).

State-Arbitrary #	County	Management	Observation dates	Location	Habitat summary	Abundance/spatial distribution/Comments	Source <sup>1</sup>
WY-19	Weston	USFS Region 2 - Thunder Basin National Grassland	20-Jun-1978	Powder River Basin, approximately 4 miles south-southeast of Rochelle; vicinity of Frog Creek.	Ridge and slopes.	In fruit. No information.	R.L. Hartman 6743 with K. Dueholm and M.A. Sanguinetti 20-Jun-1978 RM, NY; Wyoming Natural Diversity Database (2003)
WY-20	Converse	USFS Region 2 - Thunder Basin National Grassland	24-May-1993	Eastern Plains, Cheyenne River region; approximately 1.5 miles south and 1.7 miles east of the Cheyenne River on Claretton Road (County Rd 39); approximately 5.5 miles northeast of Dull Center; approximately 62.5 miles north-northeast of Douglas.	Ridge and slopes. Eroded slopes.	No information.	Wyoming Natural Diversity Database (2003); B.E. Nelson 25147 RM
WY-21	Campbell	Private (formerly USFS Region 2 - Thunder Basin National Grassland)	20-May-1981, 20-May-1985	Powder River Basin; approximately 20 air miles southeast of Reno Junction.	"Sagebrush grassland, eroded, shaley slopes, scoria hills with scattered ponderosa pine; eroded slopes." "Eroded slopes in sagebrush grassland."	No information.	Wyoming Natural Diversity Database (2003); K.H. Dueholm 11021 RM 1981
WY-22	Campbell	State of Wyoming (within USFS Region 2 - Thunder Basin National Grassland)	21-May-1978	Powder River Basin; approximately 0.5 miles north of Campbell-Converse County Line in the vicinity of Spring Creek.	Heavily grazed plains.	No information.	K.H. Dueholm 1206 with R.L. Hartman RM; Wyoming Natural Diversity Database (2003)
WY-23	Weston	State of Wyoming and possibly private land	23-Jun-1978, 23-Jun-1979	Eastern Plains; south of Newcastle; approximately 8 miles northeast of Morrissey (1978: near Sheep Creek). 1979 observation extended occurrence size.	1978: Sandy plains. 1979: Sandy plains, sandstone outcrops, draw; plains.	1979: In fruit. No information.	K.H. Dueholm 7308 1979 RM, NY; Wyoming Natural Diversity Database (2003)
WY-24	Johnson	BLM - Buffalo Field Office	5-Jun-1979, 14-May-1986	Powder River Basin; 7.5 to 8 miles southeast of Kaycee. In 1979 over two contiguous sections.	1979: Sagebrush plain on clay, draws; plains. 1986: Growing in gravelly soil on crest of hill; habitat relatively barren with <i>Artemisia tridentata</i> , <i>Astragalus spathulatus</i> , and lichen.	1979: In flower. No information.	J. Locklear 3 1986 RM; K.H. Dueholm 6542 1979 RM, NY

Table 1 (cont.).

State-Arbitrary #	County	Management	Observation dates	Location	Habitat summary	Abundance/spatial distribution/Comments	Source <sup>1</sup>
WY-25	Weston	USFS Region 2 - Thunder Basin National Grassland	24-May-1993	Powder River Basin; above Little Thunder Creek on Lynch Road just south of WY Highway 450; approximately 12 air miles east-northeast of Claretton.	Eroding slopes with sandstone outcrops.	No information.	B.E. Nelson 25168 RM; Wyoming Natural Diversity Database (2003)
WY-26	Johnson	BLM - Buffalo Field Office	15-May-1986	Near junction of WY Highway 192 and road marked "Jepson Draw"; approximately 4.5 mi east of bridge over Powder River (southwest of Sussex); area possibly revisited in 1991 that extended size of occurrence; precise location information unclear.	"Growing on eroded, barren slopes along rim of a large complex of ravines."	Large population.	J. Locklear 5 RM
WY-27	Weston	USFS Region 2 - Thunder Basin National Grassland, may be on in- holding	17-May-1994	Butte north of Mush Creek in the Southern Powder River Basin, Southeastern Plains.	Steep clay slopes with scattered pieces of sandstone.	No information.	B.E. Nelson 30291 RM
WY-28	Johnson	Not reported	7-May-1991	Vicinity 10 miles northeast of Sussex.	No information.	No information.	Wyoming Natural Diversity Database (2003)
WY-29	Johnson	Not reported	5-Jun-1979	Powder River Basin; approximately 10 miles northeast of Kaycee.	Rolling plains.	In fruit. No information.	K. H. Dueholm 6662 NY
WY-30	Johnson	State of Wyoming	1986, 8-May-1991	Powder River Basin; approximately 11 miles north of Kaycee; occurrence over two contiguous sections.	1986: Growing on the west slope of low clay hills; habitat barren with <i>Artemisia tridentata</i> , <i>Astragalus</i> sp., and lichen. 1991. Two subpopulations "On pale, sparsely-vegetated sandy silty soil on north side of knoll" and on west slopes of clay hills."	Estimated one of the sub-occurrences had 100 to 200 plants, estimated 5 percent in flower, remainder vegetative.	Wyoming Natural Diversity Database (2003); J. Locklear 4 1986 RM
WY-31	Johnson	BLM - Buffalo Field Office	1983, 9-May-1991	Powder River Basin; just northwest of Mayoworth in vicinity of Bentonite Mine.	"Badlands-like area; on pale, sparsely vegetated sandy-silty stratum." 1991: with <i>Artemisia tridentata</i> , <i>Agropyron spicatum</i> , and <i>Carex filifolia</i> . Clay hills.	1991: Estimated 500 to 1,000 individuals; scattered as clusters (locally common); estimated 70 percent bud/flower, remainder vegetative.	Wyoming Natural Diversity Database (2003); R. Dorn 3826 12-Jun-1983 RM

Table 1 (cont.).

State-Arbitrary #	County	Management	Observation dates	Location	Habitat summary	Abundance/spatial distribution/Comments	Source <sup>1</sup>
WY-32	Johnson	BLM - Buffalo Field Office	29-Jun-1979, 8-May-1991	1979: Powder River Basin along Powder River Breaks. 1991: Powder River Breaks 2 to 4 miles west of Powder River on divide between School Section Draw and Curtis Draw and on badlands-like breaks to north; over 10 contiguous sections.	1979: Clay slopes, bottoms of draws, sagebrush plains on level areas; slopes, plains. 1991: "Badlands-like river breaks: on pale, sparsely-vegetated, sandy-silty stratum, often with popcorn texture." "With <i>Artemisia tridentata</i> , <i>Agropyron spicatum</i> , and <i>Phlox hoodii</i> .	1991: One sub occurrence estimated 1,000 to 3,000 individuals; locally common; estimated 80 percent bud/flower, remainder vegetative. Second sub- occurrence estimated 500 to 1,000 individuals, scattered though area (locally common); both vegetative and flowering plants seen.	K.H. Dueholm 7473 1979 RM; Wyoming Natural Diversity Database (2003)
WY-33	Weston	USFS Region 2 - Thunder Basin National Grassland	8-Jun-2003	Western High Plains, just north of Iron benchmark on clay knoll. Driving northwest on Hwy 16 from Osage to Upton, the knoll can clearly be seen below the hill's peak (Iron benchmark).	"On silt-clay with gravel sized and larger rocks mixed in, in full sun, 5-30% slope." Occurs with species of <i>Hymenoxys</i> , <i>Lesquerella</i> , and <i>Eriogonum</i> .	100 to 200 individuals. "Additional plants were seen on clay mounds to the north, closer to road and on clay in the right of way just north of the highway.	Wyoming Natural Diversity Database (2003); P. Ebertowski RM
WY-34	Campbell	BLM or private land	18-Aug-1978	Powder River Basin; south of Caballo Creek west of Burlington Northern Railroad; occurrence possibly revisited or extended in size in 1991; precise location information unclear.	Sagebrush grassland; shallow soil.	Vegetative plants.	M. Davis s.n RM
WY-35	Campbell	BLM or private land	9-Jun-1978	Powder River Basin; 18 miles south-southeast of Gillette within 2 miles of Occurrence WY-34.	Rocky slopes and plains below; plains.	"Specimen has flowers and fruit."	R.L. Hartman 6445 RM
WY-36	Johnson	BLM - Buffalo Field Office	8-May-1991	Approximately 2 miles east of Trabing and Crazy Woman Creek; along ridge crest, road, and slopes on west side of gulch in the Powder River Basin.	On small ridge crest and slopes to east and north on pale sandy silty soil; with <i>Artemisia tridentata</i> , <i>A. pedatifida</i> , and <i>Carex filifolia</i> .	Estimated 200 to 500 individuals in area surveyed; locally common in a few small areas; estimated 20 percent in bud/flower, remainder vegetative.	Wyoming Natural Diversity Database (2003)

Table 1 (cont.).

State-Arbitrary #	County	Management	Observation dates	Location	Habitat summary	Abundance/spatial distribution/Comments	Source <sup>1</sup>
WY-37	Campbell	USFS Region 2 - Thunder Basin National Grassland	25-May-2003	Powder River Basin; approximately 0.35 miles north of Weston to FS Rd 908.	Outcrop along low ridge, at crest of ridge, east-northeast aspect, mainly 5 percent slope, on calcareous orange silt with high content of fine sand. The sparse vegetation is dominated by <i>Artemisia tridentata</i> ssp. <i>wyomingensis</i> / <i>Elymus</i> sp.	"In fruit and flower with 20% just in fruit, 50% still with some flowers and 20% vegetative. Occasional; 80-100 plants estimated (64 counted) in area of approximately 5x15m. Plants are almost all small, less than 10 cm diameter. The largest plants are eroded out."	Wyoming Natural Diversity Database (2003)
WY-38	Campbell	USFS Region 2 - Thunder Basin National Grassland	29-May-2003	Powder River Basin; approximately 16 miles northeast of Weston on Rocky Point Road and approximately 3 miles south from road to Ranch.	Upper slopes of tallest eroded prairie knolls at the headwall of a forested drainage. Occurs with <i>Artemisia tridentata</i> ssp. <i>wyomingensis</i> , <i>Elymus spicatus</i> , <i>Chrysothamnus</i> spp., <i>Koeleria macrantha</i> , <i>Penstemon albidus</i> , and <i>Erigeron pumilus</i> .	600+ plants estimated, including 60 percent flowering, 35 percent in fruit, and 5 percent vegetative.	J. Proctor personal communication (2004); Wyoming Natural Diversity Database (2003)
WY-39	Campbell	USFS Region 2 - Thunder Basin National Grassland	3-May-2003	Powder River Basin; approximately 5.5 air miles north east of Weston, near oil well on FS Rd 1247B.	"Badlands knoll just above steep ravine and below clay balds, 30% slope, south aspect. Knoll is the least steep portion of a tan layer." Occurs with <i>Artemisia tridentata</i> ssp. <i>wyomingensis</i> , <i>Elymus spicatus</i> , <i>Chrysothamnus</i> spp., <i>Koeleria macrantha</i> , <i>Penstemon albidus</i> , and <i>Erigeron pumilus</i> spp., and <i>Musineon</i> spp.	"3 fruiting and 3 vegetative plants on less than 20 x 20 ft."	Wyoming Natural Diversity Database (2003)
WY-40	Campbell	BLM - Buffalo Field Office, State of Wyoming	26-May-2003	Powder River Basin; approximately 16 miles northeast of Weston on Rocky Point Road and 0.9 miles south on road to Ranch; above the road and west of it.	"Ridgeline above valley with two small outcrop knolls, on mainly north and west aspects at primarily ridge crests and upper slope positions. A third tiny subpopulation lies on an outcrop in the saddle between knolls. Sparse vegetation; occurs with <i>Eriogonum pauciflorum</i> ."	"65% flowering, 25% in fruit, 10% vegetative. Population estimate 600-650 (524 counted); with over 70% in Sec. 25 north of the fence line. There are many large plants (>10 cm diameter) and all size classes represented."	Wyoming Natural Diversity Database (2003)

Table 1 (cont.).

State-Arbitrary #	County	Management	Observation dates	Location	Habitat summary	Abundance/spatial distribution/Comments	Source <sup>1</sup>
WY-41	Sheridan	BLM - Buffalo Field Office	11-May-1991	Breaks west of river; approximately 3 miles southwest of the confluence with Clear Creek in the Powder River Basin.	"Sparsely vegetated, multi-hued, badlands-like river breaks: on pale yellow, sandy stratum."	"Estimated 500-1,000 individuals" Scattered intermittently through area (locally abundant); all vegetative; some mats very large (to 18" diameter)."	Wyoming Natural Diversity Database (2003)
WY-42	Sheridan	BLM - Buffalo Field Office	11-May-1991	Breaks, east of river; approximately 6 miles south of Wyoming/Montana state line on ridges of Gray Cabin Draw.	"Pine ridge: Ridgecrest and upper slopes on sandy soil below sandstone outcrops. With <i>Agropyron smithii</i> , <i>Yucca glauca</i> , <i>Phlox hoodii</i> , <i>Andropogon scoparius</i> , and <i>Pinus ponderosa</i> ." Also juniper.	"Estimated 500-1,000 individuals" Scattered intermittently through area (locally abundant); all vegetative; some very large mats, but often partially dead."	Wyoming Natural Diversity Database (2003)
WY-43	Campbell	Unreported	24-May-2003	Powder River Basin; approximately 9 miles south of Biddle, Montana near the Wyoming-Montana border.	Upper ridge slope above Dry Creek, in a sparsely-vegetated <i>Artemisia tridentata</i> ssp. <i>wyomingensis</i> habitat, in calcareous orange silt, on intact edge of roadcut.	Observed in flower.	Wyoming Natural Diversity Database (2003)
WY-44	Sheridan	BLM - Buffalo Field Office, State of Wyoming	9-Jun-1979, 10-May-1991	Approximately 18.5 miles northeast of Leter in Powder River breaks west of the river. Fence Creek Oil Field.	1979: Deep ravine, with ponderosa pine on slopes, and open, clay slopes; sandstone outcrops; outcrops. 1991: "Multi-hued river breaks: ridgecrests and upper slopes, on a sparsely vegetated, pale-colored, sandy-silty stratum that often has a popcorn-textured surface." "With <i>Artemisia tridentata</i> , <i>Agropyron spicatum</i> , and <i>Chrysothamnus</i> ."	Estimated 5,000 to 10,000 individuals; scattered intermittently over large area, locally abundant or even dominant; estimated 90 percent in bud/flower; many large mats (e.g. to 12" diameter).	K.H. Dueholm 6791 1979 RM, NY; Wyoming Natural Diversity Database (2003)
WY-45	Johnson	Unknown	Sep-1900	"Buffalo."	No information.	No information.	F. Tweedy 3156 1900 RM, NY (det. M. Roberts); Wyoming Natural Diversity Database (2003)
WY-46	Converse	USFS Region 2 - Thunder Basin National Grassland	03-Jun-2005	Near Teepee.	The occurrence extended along the ridgeline on both east and west aspects.	At least, probably more than, 500 individuals.	K. Schmitt personal communication (2005)

Table 1 (cont.).

State-Arbitrary #	County	Management	Observation dates	Location	Habitat summary	Abundance/spatial distribution/Comments	Source <sup>1</sup>
SD-1	Fall River	USFS Region 2 - Buffalo Gap National Grassland, may extend into private land	23-May-1948, 20-May-1970, 28-May-1984, May-1991	1948: High on small grey mound east base of Limestone Butte 2.5 miles east-southeast of Oelrichs. 1970: Limestone Butte, 2.5 miles east, 1 mile south of Oelrichs. 1984, 1991: Limestone Butte, 2 miles east and 0.5 miles south of Oelrichs.	1948: No information. 1984, 1991: On low, white gumbo clay mounds on northeast and east sides of butte. Occasional. Plants occur on clay mounds and scree slopes.	Isely (1981) remarked on the 1948 specimen sheet that flowers were unusually small 10mm but that another specimen at this locality had flowers 16 mm. 1984: Locally abundant. 1991: Estimated 4,500 individuals (including seedlings and young plants without woody caudex) over 2 sections.	South Dakota Natural Heritage Program (2003); Muechau et al. (1991); S. Stephens 38259 1970 NY; 1948: C.A. Barr 2011, 2012, 2013; C.A. Barr and E.T. Wherry s.n. HERB BARR. Topotype C.L Parker 1956
SD-2	Fall River	USFS Region 2 - Buffalo Gap National Grassland and private land	20-May-1970	2 miles south and 2.5 miles east of Oelrichs.	Low, flat, barren prairie pasture. Abundant in dry, gravelly, clay soil.	No information.	H.A. Stephens 38248 KANU; S. Stephens 38248 NY; South Dakota Natural Heritage Program (2003)
SD-3	Fall River	USFS Region 2 - Buffalo Gap National Grassland	17-May-2001	Approximately 10 miles east-southeast of Oelrichs.	“Eroding badlands butte of Chadron formation on northeast-facing slope from crest to low.”	Vigorous cushions scattered with dead ones over approximately 2 acres. 90 percent flowering.	Erk (2003); South Dakota Natural Heritage Program (2003)
SD-4	Fall River	USFS Region 2 - Buffalo Gap National Grassland	11-May-2001	Approximately 9 miles east-southeast of Oelrichs.	“Eroding badlands butte of Chadron formation. East-northeast facing slope on crest and upper slopes.”	“Scattered plants of varied age on 50' x 10' area. 90% in flower on May 11.”	South Dakota Natural Heritage Program (2003)

Table 1 (cont.).

State-Arbitrary #	County	Management	Observation dates	Location	Habitat summary	Abundance/spatial distribution/Comments	Source <sup>1</sup>
SD-5	Pennington	USFS Region 2 - Buffalo Gap National Grassland	28-Apr-1986, May-1991	Railroad Buttes area; south edge of Railroad Buttes badlands 1 mile east of Folsom School.	1986: Along north-facing ridge where grassland table drops to badlands. 1991: Along the ridges. Plants were where "the grassy plains turn to more barren knolls and gullies.	1986: Several 1,000 plants occurring as scattered colonies along a length of 2 to 3 miles. 1991: 8,905 individuals in one sub-population and 9,300 in the second. Additional sections surveyed in 1991: 3 more sub populations - 1,380 individuals, 17,711 individuals, 100+ individuals. Total in south Railroad Butte area was 38,296 of various ages, sizes, and reproductive stages (Muenchau et al. 1991a).	South Dakota Natural Heritage Program (2003); Muenchau et al. (1991a)
SD-6	Pennington	USFS Region 2 - Buffalo Gap National Grassland	May-1991	Railroad Buttes area.	Plants on gray to white (gumbo) calcareous clay soil. Plants on bare knolls, butte tops, down the length of washed draws.	Approximately 2,300 individuals.	Muenchau et al. (1991a)
SD-7	Shannon	Native American tribal lands	29-May-1984	Cedar Bluffs (Cedar Butte); approximately 6 miles west of Oglala.	On shallow slope of mound, mostly barren, cracked. Occurs on low white, gumbo clay mounds.	Several hundred plants.	South Dakota Natural Heritage Program (2003)
SD-8	Pennington	USFS Region 2 - Buffalo Gap National Grassland	28-Sep-1988	Indian Creek; 1.5 miles southwest of Scenic.	"On mostly barren rock ledges, gumbo" "mostly broken badlands."	Several colonies of several hundred plants.	South Dakota Natural Heritage Program (2003)
SD-9	Pennington	USFS Region 2 - Buffalo Gap National Grassland, South Dakota State land, and private land	18-May-1988, 27-May-1988, May-1993	1988: (1) Spring Draw allotment, approximately 0.5 miles west of Scenic; (2) Scenic Flats, 1 mile east of Scenic; (3) Junkyard Buttes, 0.5 miles south of Scenic. 1993: Spring Draw, Scenic Basin region - plants reported from an additional seven sections.	1988: 3 sub-occurrences: (1) Barren clay flat north of road. (2) "Plants concentrated around areas of micro-relief and cobble mostly level and barren clay flats punctuated by badland mounds and wash." (3) Plants "on rocky north-facing slopes mostly barren and rocky badlands butte just east of paved road."	1988: 3 sub-occurrences: (1) "Locally abundant just north of junk pile, including plants on road cut." "lots of dead" (2) "several thousand plants" (3) "several hundred plants occurring as small isolated colonies."	D.J. Ode 88-1 1988 SS in South Dakota Natural Heritage Program (2003); D.J. Ode 88-25 1988 BHSC; D.J. Ode 88-10 1988 in South Dakota Natural Heritage Program (2003); 1993: Survey forms Wall Ranger District (Erk 2003)

Table 1 (cont.).

State-Arbitrary #	County	Management	Observation dates	Location	Habitat summary	Abundance/spatial distribution/Comments	Source <sup>1</sup>
SD-10	Custer	USFS Region 2 - Buffalo Gap National Grassland	27-May-1993	Imlay Sheep allotment.	Eroded Brule-Chadron Badlands - outwash plain, drainages. "More sand here than usual." No <i>Astragalus barrii</i> at all on east and north of unit.	95 percent flowering. Plants growing in livestock trails.	D. Schmoller field survey form received from Erk (2003)
SD-11	Fall River	USFS Region 2 - Buffalo Gap National Grassland and possibly private land	May-1991	Wayne Burgess's Butte.	Plants are common in washes and on slopes of washes. They were on the top and upper one quarter of the butte. Plants grew in patches on weathered calcareous soil that contained limestone rocks and pebbles.	Approximately 300 plants.	Muenchau et al. (1991a)
SD-12	Shannon	Native American tribal lands	26-May-1988	Upper Cedar Creek; 11 miles south and east of Red Shirt.	"Along the rim of barren badlands drainage where it meets the grassland plain."	"160 genets counted along eroded edge of grassland table. None found in white MOU."	D.J. Ode 88-15 1988 SS in South Dakota Natural Heritage Program (2003)
SD-13	Shannon	Native American tribal lands	26-May-1988	South Red Shirt Table; 13 miles south and east of Red Shirt.	On mostly barren clay flats with species of <i>Allium</i> , <i>Agropyron</i> , and <i>Musineon</i> ; mostly barren. badlands mounds and white clay flats in grassland plain.	Approximately 50,000 plants.	South Dakota Natural Heritage Program (2003); D.J. Ode 88-14 1988 BHSC
SD-14	Shannon	Badlands National Park	18-May-1988	Southwest of Stronghold Table.	On mostly barren and broken badland ridges, slopes, shelves and outwash.	"Several hundred plants on finger ridges below rim just west of neck in stronghold."	South Dakota Natural Heritage Program (2003)
SD-15	Shannon	Badlands National Park and Native American tribal lands	17-May-1988	Cottonwood Pass.	Chalcedony strewn, white badlands with broken to undulating, low pass, outwash and slopes. In fine sandy clay.	Locally common on level 0.5-mile transect. At the upper end of corral.	D.J. Ode 88-5 1988 SS in South Dakota Natural Heritage Program (2003)
SD-16	Shannon	Badlands National Park and Native American tribal lands	25-May-1988	Battle Creek Canyon southwest of Plenty Star Table; approximately 7 miles southeast of Red Shirt.	On badland slopes, mounds.	"About 100 plants observed in widely scattered colonies."	South Dakota Natural Heritage Program (2003)
SD-17	Shannon	Badlands National Park and Native American tribal lands	1988	Quinn Draw, just east of Plenty Star Table; approximately 7 miles east of Red Shirt.	On mostly barren badland slopes.	"Several thousand plants as localized colonies."	South Dakota Natural Heritage Program (2003)

Table 1 (cont.).

State-Arbitrary #	County	Management	Observation dates	Location	Habitat summary	Abundance/spatial distribution/Comments	Source <sup>1</sup>
SD-18	Shannon	Badlands National Park and Native American tribal lands	22-May-1984	An isolated butte on south side of Sheep Mountain Table; approximately 10 miles south of Scenic (north Cedar Butte).	“On barren outcrops of rockyford member, Occurs on north-facing scree slope ridges along south and southwest periphery of butte top.”	“Two populations found of 4 and 67 plants.”	D.J. Ode 84-14 SS in South Dakota Natural Heritage Program (2003)
SD-19	Shannon	Badlands National Park and Native American tribal lands	17-May-1988	North Cactus Flats.	Isolated badland mounds and barren knolls in western wheatgrass-blue grama grass.	Several hundred genets observed in two locations, one on steep northwest-facing slope.	D.J. Ode 88-8 SS in South Dakota Natural Heritage Program (2003)
SD-20	Custer	USFS Region 2 - Buffalo Gap National Grassland	31-May-1988	Red Shirt Creek; 4 miles west-northwest of Red Shirt.	“On rocky, badland slopes, shelves.”	“Several thousand plants in localized colonies.”	South Dakota Natural Heritage Program (2003)
SD-21	Custer	USFS Region 2 - Buffalo Gap National Grassland; may extend to Native American tribal lands	26-May-1988	Kaiser allotment; 20.5 miles southeast of Hermosa.	“Rocky river breaks and badlands with lots of sandstone out-crops.”	“Several thousand plants as localized colonies on mostly barren sandstone ridges.”	South Dakota Natural Heritage Program (2003)
SD-22	Pennington	USFS Region 2 - Buffalo Gap National Grassland	3-May-1986	East flank of Sheep Mountain Table; 2 miles west of Scenic.	Badland mounds, washes and sod tables along the east base of Sheep Mountain Table.	“Over 200 plants counted occurring as scattered colonies of 5 to 30 plants on most mounds.”	South Dakota Natural Heritage Program (2003)
SD-23	Custer	Bankhead-Jones Land Use Lands (L.U. Lands)	1-Jun-1988	Shorty Draw; approximately 10 miles east of Fairburn.	On ledges of rimrock.	“Several hundred plants observed along north-south fence line.”	South Dakota Natural Heritage Program (2003)
SD-24	Custer	USFS Region 2 - Buffalo Gap National Grassland	3-Oct-2001	Southwest pasture; Triple 7 allotment.	“Eroding badlands outcrops within mixed grass prairie.”	“Plants observed in two locations.”	South Dakota Natural Heritage Program (2003)
SD-25	Fall River	USFS Region 2 - Buffalo Gap National Grassland and possibly private land	1-Jun-1988, May-1991	Kennedy's Butte; approximately 9 miles east of Smithwick.	1988: “An isolated, low butte capped with limestone in level to rolling grassland.” 1991: “Limestone-capped butte with limestone pebbles to boulders (gumbo with various rocks).”	1988: “About 200 plants on mostly barren rock outcrop near top of Butte.” 1991: Total of 708 individuals counted. Plants were on all slopes in various stages of growth, including full flower. Most 5-13 in diameter. Dead plants were noted.	South Dakota Natural Heritage Program (2003); Muenchau et al. (1991a)

Table 1 (cont.).

State-Arbitrary #	County	Management	Observation dates	Location	Habitat summary	Abundance/spatial distribution/Comments	Source <sup>1</sup>
SD-26	Custer	USFS Region 2 - Buffalo Gap National Grassland; may extend to private and/or Native American tribal lands	28-May-1993	Buttes north of Red Shirt.	No information.	No information.	Hoy et al. (1993b)
SD-27	Pennington	Likely private outside USFS Region 2 - Buffalo Gap National Grassland	30-May-1970	5 miles northeast Scenic.	Flat with <i>Astragalus missouriensis</i> and an occasional <i>A. racemosus</i> .	No information.	M. Rever 150 with S. Gibney NY
NE-1	Dawes	Private land	1991	Northeast of Chadron.	On a bare limestone butte.	Approximately 850 plants.	Muenchau et al. (1991a)
MT-1	Rosebud	BLM - Miles City Field Office	13-Jul-1992	Approximately 23 miles north-northeast of Vananda.	“Sparse vegetation (80% bare ground) on rocky, windblown outcrops, with <i>Artemisia tridentata</i> , <i>Agropyron spicatum</i> , <i>Eriogonum pauciflorum</i> , and <i>Lesquerella alpina</i> . Mining addition on west side of hill.”	Three small areas with approximately 30 plants total; several plants flowering.	Montana Natural Heritage Program (2003); L.S. Roe 492 MONT [Specimen had a temporary placeholder citation]
MT-2	Rosebud	Private land	20-May-1975	Montana State Department of Health monitoring site; 1.5 miles southeast of Colstrip; on border of watershed 10100003; over 12 sections.	“Steep butte with many road cuts and grazing marks.”	No information.	Montana Natural Heritage Program (2003); K.H. Lackschewitz 5950 1975 NY 76530 MONTU; [NY duplicate. Determined by Barneby.]
MT-3	Rosebud	Private land	18-May-1985	Approximately 0.2 miles north of Miller Coulee; approximately 4.5 miles south of Colstrip. “Just over fence from ‘Area A Reclamation’ of strip mine.”	“On barren, decomposing sandstone cap; in sparse vegetation surrounded by <i>Pinus ponderosa</i> with <i>Hymenopappus filifolius</i> , and others.”	Specimen keyed well to this species. Populations little affected by nearby land use. Ridge top to north being quarried.	Montana Natural Heritage Program (2003)
MT-4	Rosebud	Private land	28-May-1976	Approximately 5.5 km southeast of Colstrip; above borrow pit.	On sandstone hill slopes (entisol), with <i>Pinus ponderosa</i> , <i>Andropogon scoparius</i> , <i>Oryzopsis hymenoides</i> , and <i>Bromus tectorum</i> .	No information.	Montana Natural Heritage Program (2003); P.L. Plantenberg V/28/76 1 1976 MONT

Table 1 (cont.).

State-Arbitrary #	County	Management	Observation dates	Location	Habitat summary	Abundance/spatial distribution/Comments	Source <sup>1</sup>
MT-5	Rosebud	Private land	10-Jun-1996	Approximately 8.5 miles southeast of Colstrip near Cow Creek Road.	“Shale outcrop ridge tops dominated by <i>Agropyron spicatum</i> , overlying sandstone, on small escarpments in rolling plains. Associated species: <i>Pinus ponderosa</i> , <i>Rhus trilobata</i> , <i>Artemisia longifolia</i> , and <i>Astragalus gilviflorus</i> .”	Over 50 plants, 10 percent in late flowering, 90 percent vegetative; scattered on three slopes.	Montana Natural Heritage Program (2003)
MT-6	Carter	Private land	26-Apr-1905, 1943	“From Ekalaka, Montana” (Barneby, 1964; Historical record, has not been relocated).	“Gullied knolls, buttes, and barren hilltops, on limestone or sandstone” (Barneby 1964).	Montana Natural Heritage Program (2003): “Map shows numerous buttes in the vicinity of Ekalaka. But field surveys in 1986, 1988, and 1989 have not relocated this species in the Ekalaka Area.”	Montana Natural Heritage Program (2003); Schunk and Schwantz s.n. 1943 UTC
MT-7	Rosebud	BLM - Miles City Field Office	11-Jun-1996	On a sandstone ridge above Davidson Coulee.	Midslope outcrops on sandstone and overlying shale on north aspect of east-west trending ridges above creek in <i>Pinus ponderosa/Agropyron spicatum</i> habitat type. Associated species: <i>Juniperus scopulorum</i> , <i>Astragalus gilviflorus</i> , and <i>Carex filifolia</i> .	“6 plants in 2 sub-populations, in vegetative condition.”	Montana Natural Heritage Program (2003)
MT-8	Powder River	USFS Region 1 - Custer National Forest	20-May-1988	Approximately 10 miles east of Ashland.	Low eroding hillside in silty-clay soils, with <i>Chrysothamnus nauseosus</i> , <i>Andropogon scoparius</i> , and <i>Gutierrezia sarothrae</i> . Appears restricted to Midway-Elso rocky soils, 35-70% slope.	Approximately 200 to 250 plants scattered along a low embankment; not flowering. Vegetative material only; confirmation in flower warranted.	Montana Natural Heritage Program (2003)
MT-9	Rosebud	USFS Region 1 - Custer National Forest	16-May-1988	King Creek Well	“Eroding hillside of silty clay soil.” With “ <i>Artemisia tridentata</i> , <i>Atriplex confertifolia</i> , <i>Yucca glauca</i> , and <i>Comandra umbellata</i> .”	“Approximately 2,000 plants, flowering prolifically; active pollination observed.”	Montana Natural Heritage Program (2003); L.A. Schassberger 185 1988 MONTU
MT-10	Rosebud	Private land	20-May-1988	Approximately 10 miles southeast of Ashland.	“In silty-clay soils, with <i>Artemisia tridentata</i> , <i>Festuca idahoensis</i> , and <i>Gutierrezia sarothrae</i> .”	“Approximately 200 plants scattered atop a cliff; 25% flowering.”	Montana Natural Heritage Program (2003); L.A. Schassberger 197 1988 MONTU

Table 1 (cont.).

State-Arbitrary #	County	Management	Observation dates	Location	Habitat summary	Abundance/spatial distribution/Comments	Source <sup>1</sup>
MT-11	Rosebud	Private land	19-Sep-1997, 30-Sep-1997	Approximately 2.5 miles up and northeast of Bridge Creek.	Sparsely vegetated slopes. Associated plants: <i>Eriogonum pauciflorum</i> , <i>Agropyron spicatum</i> , <i>Agropyron dasystachyum</i> , <i>Artemisia tridentata</i> , <i>Gutierrezia sarothrae</i> , <i>Grindelia squarrosa</i> , <i>Astragalus gilviflorus</i> , <i>Machaeranthera grindelioides</i> , and <i>Eriogonum flavum</i> .	"Seven subpopulations with 50 - 200 individuals, at least 700 individuals in all, none in flower or fruit (1 peduncle seen)."	Montana Natural Heritage Program (2003).
MT-12	Rosebud	BLM - Miles City Field Office, Private land	20-May-1988	Less than 1 mile south of Gate Creek near Birney Creek Road.	Eroding knoll, with <i>Artemisia tridentata</i> , <i>Artemisia confertifolia</i> , and <i>Andropogon scoparius</i> .	Approximately 200 to 250 plants, flowering; evidence of livestock grazing.	Montana Natural Heritage Program (2003); L.A. Schassberger 196 1988 MONTU
MT-13	Powder River	USFS Region 1 - Custer National Forest	19-May-1988	Approximately 1 mile east of Otter Creek, north of Lyon Creek Road.	Eroding cliff-lines and ridges, in silty clay soils, beneath <i>Pinus ponderosa</i> and <i>Juniperus scopulorum</i> ; with <i>Andropogon scoparius</i> , <i>Festuca idahoensis</i> , and <i>Senecio canus</i> . Restricted to Midway-Elso rocky soils, 35 to 70 percent slope.	Approximately 2,400 plants in four subpopulations; large matted populations, not flowering. Light grazing in surrounding areas. Restriction of this population to siltstone rather than any extension into sandstone supports <i>Astragalus barrii</i> determination." "Vegetative material only; confirmation in flower warranted."	Montana Natural Heritage Program (2003); L.A. Schassberger 184 1988 MONTU
MT-14	Rosebud	State Trust land	22-Jun-2001	Whitten Creek; approximately 2.5 miles southwest of Birney.	"Ponderosa pine-Rocky Mountain Juniper. Hills of red shale and sandstone, and badlands. Northwest-facing knob of badlands, very sparsely vegetated. An occasional greasewood shrub, Juniper or ponderosa pine. Bluebunch wheatgrass present. Associated species include <i>Sarcobatus vermiculatus</i> , <i>Pinus ponderosa</i> , <i>Juniperus scopulorum</i> , <i>Cryptantha</i> sp., and <i>Agropyron spicatum</i> . <i>Astragalus gilviflorus</i> common on same hills."	"4 major mats/clumps (approximately 12 cm wide) on knob. Fruiting with some remnant flowers."	Montana Natural Heritage Program (2003); A. Taylor 8672 2001

Table 1 (cont.).

State-Arbitrary #	County	Management	Observation dates	Location	Habitat summary	Abundance/spatial distribution/Comments	Source <sup>1</sup>
MT-15	Rosebud	BLM and/or Private land	2002	Whitten Creek; approximately 3.5 miles west of Birney; site is in eroding badlands to the northeast of stock tank.	Sandstone and siltstone rock outcrop near the top of an eroding knob, sparsely vegetated. Steep-slopes (30 percent) and quite eroded, with many drainage channels and the north side with significantly more vegetation. Soil fine silty-clay with many small shale-like fragments, reddish when dry. 75 percent bare ground, the rest mostly rock and gravel. Dominants: <i>Pinus ponderosa</i> (2%), <i>Juniperus scopulorum</i> (2%), and <i>Agropyron spicatum</i> (3%). Microhabitat dominated by <i>Agropyron spicatum</i> , <i>Haplopappus acaulis</i> , and <i>Phlox hoodii</i> , with some <i>Rhus trilobata</i> . <i>Pinus ponderosa</i> and <i>Juniperus scopulorum</i> nearby, but denser in other areas in the vicinity. Associated: <i>Haplopappus acaulis</i> , <i>Phlox hoodii</i> , <i>Rhus trilobata</i> , <i>Hymenopappus filifolius</i> , <i>Comandra umbellata</i> , <i>Cryptantha celosioides</i> , <i>Artemisia tridentata</i> , and <i>Chaenactis</i> sp.	Over 200 clumps well-dispersed over about 1/3 acre of dry, open ridge crest; 60 percent flowering and 40 percent vegetative; plants occurred on both a southeast aspect and a northwest aspect; though plants smaller and fewer-flowered on southeast slope." Site is in eroding badlands to the north east of stock tank" Surveyed along ridge into more vegetated area and walked around the immediate habitat; no other populations located; however, much additional potential habitat on private lands in the area.	Montana Natural Heritage Program (2003)
MT-16	Powder River	USFS Region 1 - Custer National Forest	14-May-1988, 14-Jun-1995	Approximately 0.25 miles northwest of Fort Howes Ranger Station.	Eroding hillside and above siltstone cliff with <i>Artemisia tridentata</i> , <i>Gutierrezia sarothrae</i> , <i>Cryptantha celosioides</i> , and <i>Yucca glauca</i> . On Midway Elso rocky soils, 35 to 70 percent slope.	1988: "Approximately 600 plants, in 2 subpopulations; most in flower." 1995: 50 plants, 90 percent in flower.	Montana Natural Heritage Program (2003); L.A. Schassberger 178 1988 MONTU
MT-17	Powder River	USFS Region 1 - Custer National Forest	19-May-1988	Approximately 1.5 miles north of Fort Howes Ranger Station; southwest of Stag Rock.	Eroding cliff-lines in silty-clay soils, beneath moderate cover of <i>Pinus ponderosa</i> and <i>Juniperus scopulorum</i> with <i>Calamovilfa longifolia</i> , <i>Artemisia tridentata</i> , and others.	Approximately 4,000 plants in 10 subpopulations scattered along cliff-line; about 50 percent in flower; large mats.	Montana Natural Heritage Program (2003); L.A. Schassberger 190, 191 1988 MONTU

Table 1 (cont.).

State-Arbitrary #	County	Management	Observation dates	Location	Habitat summary	Abundance/spatial distribution/Comments	Source <sup>1</sup>
MT-18	Powder River	USFS Region 1 - Custer National Forest	24-May-1995	Ridge northwest of confluence of Horse and Otter creeks approximately 2.5 miles south of Fort Howes work center; two subpopulations approximately 0.8 miles apart.	Partially shaded, dry crest and upper slope with small sandstone outcrops. Sandy-silty breaklands. On Midway-Elso rocky soils, 35 to 70 percent slope. <i>Pinus ponderosa</i> and <i>Juniperus scopulorum</i> with sparse under story dominates southern subpopulation. <i>Astragalus barrii</i> dominates northern population.	Southern subpopulation has approximately 50 plants, >90 percent flowering, remainder vegetative. Northern subpopulation has 150-200 plants, approximately 75 percent flowering, remainder vegetative. Natural erosion of steeper slopes has produced pedestaled plants.	Montana Natural Heritage Program (2003)
MT-19	Powder River	USFS Region 1 - Custer National Forest	19-May-1988	Approximately 0.75 miles southeast of Fort Howes Ranger Station, along cliffs; over three sections.	Eroding cliff in silty-clay soils; One subpopulation in the middle of a burn area (1966). Open <i>Pinus ponderosa</i> and <i>Juniperus scopulorum</i> , with <i>Artemisia tridentata</i> and <i>Haplopappus armerioides</i> . On Midway-Elso rocky soils, 35 to 70 percent slope.	Approximately 3,050 plants scattered along rim-rock. Large mats. Not flowering. Additional subpopulation has approximately 2,000 individuals scattered above and below cliff line. Restriction of this population complex to supports the <i>Astragalus barrii</i> determination." "Vegetative material only; confirmation in flower warranted."	Montana Natural Heritage Program (2003); L.A. Schassberger 179 1988 MONTU
MT-20	Powder River	USFS Region 1 - Custer National Forest, Private land	24-May-1995	Southeast of Otter; approximately 1.5 miles southwest of the confluence of Bear and Otter Creeks.	"Dry, open lower-to-midslope breaklands. Reported to be sandstone material. Associated species: <i>Phlox hoodii</i> , <i>Comandra umbellata</i> , <i>Astragalus gilviflorus</i> , and <i>Hymenopappus polyccephalus</i> . On Midway-Elso rocky soils, 35-70% slope."	200 to 250 plants, 90 percent in flower 10 percent vegetative. Population is very close to a road.	Montana Natural Heritage Program (2003); Marriott 11498 1995 MONTU
MT-21	Powder River	BLM - Miles City Field Office	21-May-1986	Powder River badlands; 0.2 to 0.45 miles east of the Butte Creek Road south of its junction with the Powder River Road; over two sections.	"Eroding in silt-clay soils in barren, level to sloping areas with <i>Artemisia tridentata</i> / <i>Agropyron spicatum</i> , <i>Juniperus scopulorum</i> , <i>Astragalus spatulatus</i> , and <i>A. gilviflorus</i> . On Midway and Elso rocky soils, 35-70% slope."	"Approximately 70 to 80 plants distributed in two subpopulations; 50% in flower and early fruit; some signs of light grazing." May be a relocation of a historical collection "Butte Creek" cited by Barneby (1956).	Montana Natural Heritage Program (2003); J.S. Shelly 1064 1986 MONTU; Mrs. Considine s.n. No date at "HERB BARR" [C. Barr's herbarium] in Barneby (1956)

Table 1 (cont.).

State-Arbitrary #	County	Management	Observation dates	Location	Habitat summary	Abundance/spatial distribution/Comments	Source <sup>1</sup>
MT-22	Powder River	BLM - Miles City Field Office	1989, 18-Jun-2000	Approximately 1.2 miles north of the Belle Creek Road.	“Silty clay knobs, knolls, saddles, and valley rim settings of sparse vegetation with <i>Pascopyrum smithii</i> , <i>Gutierrezia sarothrae</i> , <i>Astragalus spatulatus</i> , and less often <i>Chrysothamnus nauseosus</i> and <i>Artemisia tridentata</i> . On Midway-Elso rocky soils, 35-70% slope. Possibly on Midway-Elso rocky soils, 8-35% slope in a landscape where they predominate.”	“2,000+ plants in low frequency but with high density subpopulations having 100s of plants.”	Montana Natural Heritage Program (2003); L.A. Schassberger (1990)
MT-23	Rosebud	BLM - Miles City Field Office, Private land	5-Jul-1997	Approximately 5.5 miles north of Vananda.	On prominent escarpment on midslope finger ridge dominated by <i>Agropyron spicatum</i> .	No information.	Montana Natural Heritage Program (2003); B. Heidel s.n. 1997 MONT
MT-24	Big Horn	Private land	1989, 5-Jun-1991	Approximately 8 miles north-northwest of Decker Cin Spring Creek Drainage near Spring Creek Mine.	“On fine, sandy clay loam soil, above a sandstone outcrop, and bare, dry, fine soil or shale” with <i>Artemisia tridentata</i> , <i>Agropyron spicatum</i> , <i>Astragalus gihviflorus</i> , and other species.	“This occurrence contains 7 subpopulations spread over an area of roughly 4 miles east-west by 1.5 miles north-south; each subpopulation has from 20 to 1,000 plants.”	Montana Natural Heritage Program (2003); K. Fenton s.n. 1991 MONT; G.P. Hallsten 2617 1989 (in his personal collection)
MT-25	Big Horn	BLM and/or private land	2002	About 7 to 8 miles north-northwest of Decker; up a side-drainage to south Fork of Spring Creek.	“Deeply eroded landscape with rounded knobs and large sandstone/siltstone fragments. Many erosional channels cut into the soft rock. Vegetation sparse, dominated by <i>Agropyron spicatum</i> , <i>Artemisia tridentata</i> , <i>Pinus ponderosa</i> (1% cover), and <i>Juniperus scopulorum</i> . Badlands ecological site. Area was surveyed NE to another cross fence; W side was also surveyed.”	“Estimate 500-700 clumps over 1 acre, just above the more heavily vegetated creek bottom, from horizontal to 30% slope, variable aspect. 50% fruiting. Soil surface cracked, highly erodible and plants somewhat silted over. Associates: <i>Comandra umbellata</i> , <i>Astragalus gihviflorus</i> , <i>Phlox hoodii</i> , <i>Penstemon nitidus</i> , <i>Chaenactis douglasii</i> , <i>Machaeranthera grindelioides</i> , <i>Koeleria macrantha</i> , <i>Astragalus bisulcatus</i> , and <i>Penstemon eriantherus</i> .”	Montana Natural Heritage Program (2003)

Table 1 (cont.).

State-Arbitrary #	County	Management	Observation dates	Location	Habitat summary	Abundance/spatial distribution/Comments	Source <sup>1</sup>
MT-26	Powder River	Private land	16-Jun-1961, 20-May-1986, 14-Jun-1986	Along bluff on east side of Highway 59 1.5 to 1.7 miles north of Biddle; overlooking the Little Powder River. Also just west of highway (1986, 1961).	1961: On low sandstone bluff, 3,200 ft elevation (Barneby 1961). May 1986: On low siltstone bluff; <i>Artemisia tridentata</i> /grassland, with <i>Opuntia polyacantha</i> , <i>Artemisia frigida</i> , <i>Bouteloua gracilis</i> , <i>Koeleria macrantha</i> and other spp. On Midway-Elso rocky soils, 35 to 70 percent slope. June 1986: In the breaks with <i>Artemisia tridentata</i> and <i>Eriogonum pauciflorum</i> on bentonite layers.	1961: "Forming domed cushions up to 5 dm in diameter." May 1986: "Approximately 200-250 plants, most in flower; evidence of light grazing by horses."	Montana Natural Heritage Program (2003); R.C. Barneby 13233 1961 RM, NY; P.C. Lesica 3842 June 1986 NY; J.S. Shelly 1058 May 1986 MONTU (specimen verified by M. Roberts 1977)
MT-27*	Powder River	State Trust land	20-May-1986	Approximately 2 miles east-southeast of Biddle, north of Ranch Creek.	"Gullied slopes, bluffs, and along ridgelines in clay soil derived from sand and siltstone; <i>Artemisia tridentata</i> / <i>Atriplex confertifolia</i> grassland 'badland'. On Midway-Elso rocky soils, 35-70% slope, also on Midway-Elso association, 8-35% slopes."	"Approximately 600-700 plants in 10 subpopulations; flower and early fruit; evidence of livestock grazing, especially on lower slopes."	Montana Natural Heritage Program (2003); J.S. Shelly 1059 1986 MONTU
MT-27*	Powder River	BLM - Miles City Field Office, Private land	21-May-1986	Badlands along the Little Powder River; northeast of Bobcat Creek approximately 2.6 miles east-northeast of Biddle.	"Barren slopes and ridges of silt-clay soil; with <i>Artemisia tridentata</i> , <i>Atriplex confertifolia</i> , <i>Allium textile</i> , and species of <i>Penstemon</i> and <i>Zigadenus</i> . On Midway-Elso rocky soils, 35-70% slope."	Approximately 80-100 plants in 3 subpopulations (only 2 plants seen on BLM land); "Lower slopes around the sites are heavily grazed, and there is evidence of livestock on higher slopes."	Montana Natural Heritage Program (2003)
MT-28	Powder River	Private land	16-May-1989	Approximately 1.5 miles southwest of Biddle on east and west of Highway 59; over two sections.	On silty clay "gumbo" knolls and knobs with <i>Phlox hoodii</i> , <i>Artemisia tridentata</i> , and <i>Chrysothamnus nauseosus</i> . On Midway-Elso rocky soils, 35 to 70 percent slope.	"Locally common. Many plants dead in 1989 (probably due to drought)."	L.A. Schassberger 258 MONTU; Montana Natural Heritage Program (2003)

Table 1 (cont.).

State-Arbitrary #	County	Management	Observation dates	Location	Habitat summary	Abundance/spatial distribution/Comments	Source <sup>1</sup>
MT-29	Powder River	Private land	1988, 14-May-1989	Approximately 3.75 miles east of Biddle, north of Ranch Creek; over three sections.	On silty clay "gumbo" knolls and slopes, with <i>Gutierrezia sarothrae</i> , <i>Artemisia frigida</i> , and <i>Chrysothamnus nauseosus</i> . On Midway-Elso rocky soils, 35-70% slope. Possibly also on Midway-Elso association, 8-35% slope."	"Locally common. Many plants dead in 1989 (probably due to drought)."	L.A. Schassberger 255 1989 MONTU; Montana Natural Heritage Program (2003)
MT-30	Powder River	BLM - Miles City Field Office	31-May-1999	Two miles south of Belle Creek Road and approximately 4.5 miles east of State Highway 59.	"Small siltstone outcrop on main ridge between two more broken side. <i>Stipa comata</i> and <i>Machaeranthera grindelioides</i> . On Midway-Elso formation, 35-70% slope."	"More than 200 plants in fruit and late flowering."	Montana Natural Heritage Program (2003)
MT-31	Big Horn	Private land	18-Jun-1983	Approximately 1 mile south of Squirrel Creek west of the Decker-Sheridan Road; over nine sections.	Barren clay soil on ride top, with <i>Haplopappus acaulis</i> and <i>Eriogonum pauciflorum</i> .	Common.	P. Lesica 2604 MONTU, NY
MT-32	Powder River	BLM - Miles City Field Office	1986, 28-May-1999	Butte Creek Road, west of Wild Bill Creek and approximately 2 miles west of State Highway 59.	In silt-clay soil along a low ridgeline, with <i>Artemisia tridentata</i> , <i>Pascopyrum smithii</i> , <i>Poa secunda</i> , <i>Astragalus spathulatus</i> , and <i>Musineon divaricatum</i> . On Midway-Elso formation 8 to 35 percent slope.	"Approximately 200-225 plants, 1 population, in fruit and late flower 28 May 1999."	J. S. Shelly 1062 1986 MONTU, Montana Natural Heritage Program (2003)
MT-33	Powder River	BLM - Miles City Field Office, Private land	1989, 9-Jun-1999	Approximately 3.5 miles southeast of Biddle; survey over 10 sections; populations extended over 5 miles.	"Large dissected ridge complex with different outcrops including sparsely vegetated, silty-clay "gumbo" knolls and slopes with <i>Phlox hoodii</i> , <i>Pascopyrum smithii</i> , and <i>Artemisia tridentata</i> . On a complex of Midway-Elso rocky soils, 35-70% slopes and Midway-Elso soils, 8-35% slope."	"Locally common on small outcrops spanning over 5 miles. Over 30 sub-populations, tallied over 5,000 plants. Peak flowering May 27 1999. Bombus species were observed pollinating plants. Bordered by oil fields to east."	B. L. Heidel 1806, 1999 MONT. L.A. Schassberger 256 1989 MONT. Montana Natural Heritage Program (2003)
MT-34	Powder River	BLM - Miles City Field Office, Private land	1988, 15-May-1989	Approximately 7 miles east of Biddle north of Ranch Creek; over three sections.	"On silty-clay 'gumbo' knolls and slopes, with <i>Artemisia frigida</i> , <i>Astragalus spathulatus</i> , and <i>Astragalus gilviflorus</i> ."	"Locally common. Many plants dead in 1989 (probably due to drought)."	Montana Natural Heritage Program (2003)

Table 1 (concluded).

State-Arbitrary #	County	Management	Observation dates	Location	Habitat summary	Abundance/spatial distribution/Comments	Source <sup>1</sup>
MT-35	Carbon	BLM and/or Private land	21-Jun-1983	Approximately 10 miles northwest of Lovell, Wyoming, east side of Crooked Creek.	Sandy slopes with <i>Hymenopappus filifolius</i> and <i>Artemisia tridentata</i> .	No information.	P.C. Lesica 2611 NY

\* May be contiguous and form one population.

<sup>1</sup> Herbarium abbreviations:

BHSC Herbarium, Biology Department, Black Hills State University, Spearfish, SD, USA.

KANU R. L. McGregor Herbarium, University of Kansas, Lawrence, KS, USA.

MONT Herbarium, Montana State University, Bozeman, MT, USA.

MONTU Herbarium University of Montana, Missoula, Montana, USA.

NY William and Lynda Steere Herbarium, New York Botanical Garden, New York, USA (see **References** section).

RM Rocky Mountain Herbarium, University of Wyoming, Laramie, Wyoming, USA.

UTC Intermountain Herbarium, Utah State University, Logan, Utah, USA.

*Orophaca* section as “bun” plants owing to the cushion-like growth habit (**Figure 1**). The plants rarely exceed 10 cm (3.9 inches) in height, but the mats may reach approximately 45 cm (17.7 inches) across.

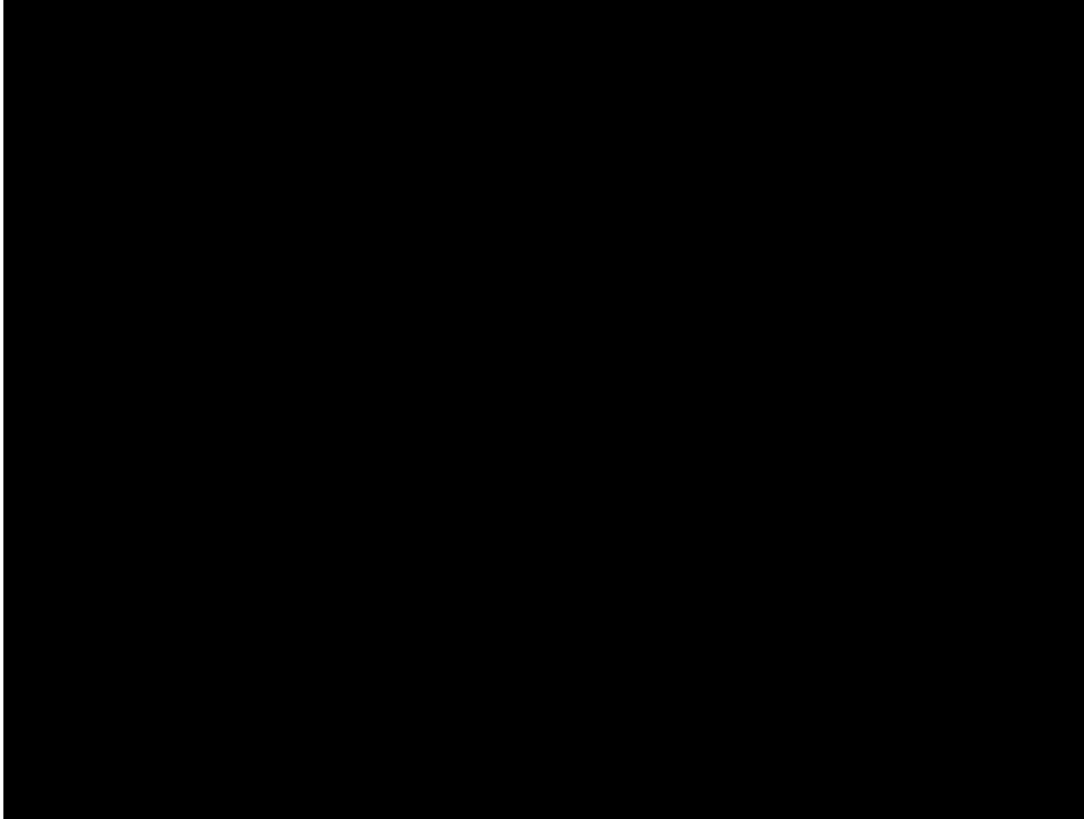
*Astragalus barrii* has prostrate woody stems that have numerous leaves. Each leaf has three narrow elliptic leaflets, which are 1 to 4 cm (0.04 to 0.16 inches) long. The stems and leaves are densely covered with short, white, silvery hairs. These hairs are dolabriform, that is T-shaped like a teeter-totter, or like a pick with a very short handle. One way to determine whether hairs are dolabriform is to push on one end of the hair, making it twist on its stalk, and noting if the other end moves in the opposite direction. Hair examination needs to be done using a microscope or hand lens. The triangular stipules (leaflet-like structures at the leaf bases) are membranous. The flower petals are relatively large, being 7 to 17 mm (0.28 to 0.67 inches) long, and of different shades of purple from pinkish to bluish. One to four flowers grow in narrow, open clusters on short (7 to 16 mm [0.28 to 0.63 inches]) stalks throughout the mat. The calyx is 4.8 to 7.1 mm (0.18 to 0.28 inches) long and also densely covered with long, white hairs.

The calyx tube is cylindrical and 3 to 5 mm (0.12 to 0.2 inches) long. The one- to few-seeded pod is narrowly elliptic in shape and sparsely covered with long white hairs. The seeds are 4 to 8 mm (0.16 to 0.31 inches) long by 1 to 2 mm (0.04 to 0.08 inches) wide (Barneby 1964, Dorn 1988, Barneby 1989, Schassberger 1990, Isely 1998, Heidel and Fertig 2003, Montana Natural Heritage Program 2005a). Roberts (1977) observed that seeds from plants growing in South Dakota were colored black whereas those in Montana were dark brown. A close-up photograph of an *A. barrii* plant is presented in **Figure 1** and an illustration in **Figure 2**.

*Astragalus barrii* plants need to be flowering during survey times. This is to ensure that they can be positively distinguished from other *Astragalus* species with three leaflets (Roberts 1977, Dorn 1988) and also because it is a cryptic plant and easily overlooked when vegetative (Dingman 2005). The combination of large flower size, moderate curvature of the banner petal, the triangular, rounded rather than blunt, blades of the keel, and the narrow calyx are the most distinctive features (Barneby 1964, Isely 1998). Other *Astragalus* species with three leaflets typically have smaller flowers and



**Figure 1.** Close-up photograph of *Astragalus barrii*. Photograph by John Proctor, Medicine Bow-Routt National Forests and Thunder Basin National Grassland.



**Figure 2.** Illustration of *Astragalus barrii* by Debbie McNeil, used with permission.

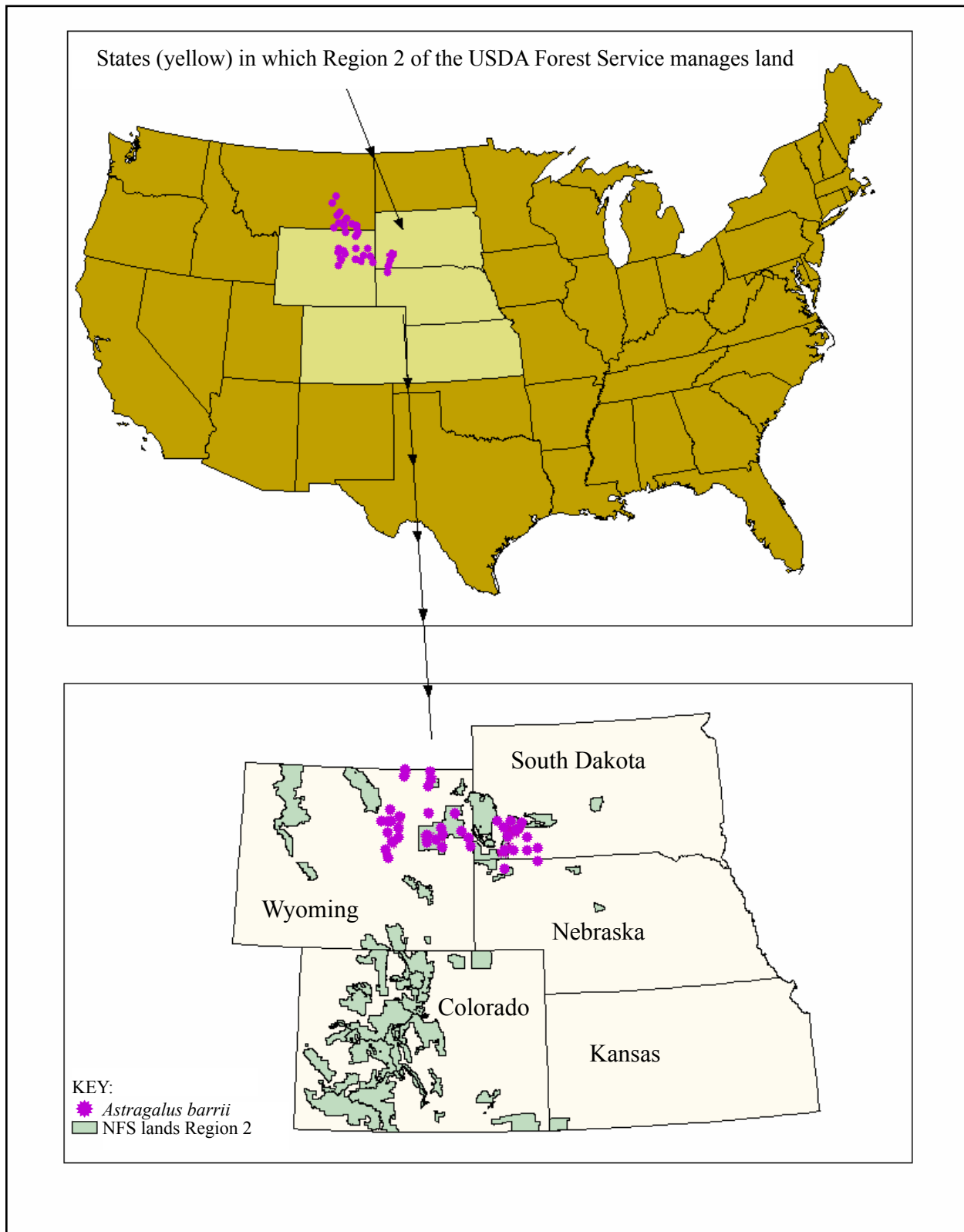
shorter calyx tubes than *A. barrii* (Dorn 1992, Fertig et al. 1994, Fertig 1998). Morphologically, *A. barrii* is most similar to *A. tridactylus*, *A. gilviflorus*, and *A. hyalinus*. It should be noted that *A. barrii* does not grow with *A. tridactylus*, but it is sympatric with *A. gilviflorus* throughout its range and with *A. hyalinus* in Montana and Wyoming (Roberts 1977, Heidel 2004). In fact, recently *A. hyalinus* was found to be more widely distributed than previously thought within the range of *A. barrii* in some parts of Montana (Heidel et al. 2002). This increases the likelihood for mistaken identity when the plants are vegetative. However, when flowering, the taxa can be definitively distinguished because the flowers of both *A. gilviflorus* and *A. hyalinus* are whitish or pale yellow to cream. *Astragalus hyalinus* also has pubescent petals. *Astragalus barrii* superficially looks like the common *A. spatulatus*, tufted milkvetch (Heidel et al. 2002). Two distinguishing differences are that the latter has distinctly elongated flowering stalks and at least some of the leaves are reduced to a leaf-like petiole with no blade (Barneby 1989). This type of leaf structure is termed a phyllode (Welsh et al. 1993). A photograph of *A. spatulatus* is published on the Nebraska Statewide Arboretum Internet site (Nebraska Statewide Arboretum undated).

#### *References to technical descriptions, photographs, and line drawings*

Detailed technical descriptions of *Astragalus barrii* are given in Barneby (1956), Barneby (1964), Roberts (1977), Dorn (1984, 1988, 1992, 2001), Great Plains Flora Association (1986), and Isley (1998, as *Orophaca barrii*). Another comprehensive technical description, a photograph, and a line drawing are published in Heidel and Fertig (2003). Other photographs published on the Internet include ones by Locklear (undated), Heidel (2004), and Montana Natural Heritage Program (2005a).

#### Distribution and abundance

*Astragalus barrii* is a regional endemic of the plains in southwestern South Dakota, eastern Wyoming, southeastern Montana, and northwestern Nebraska (**Figure 3**). It has been reported from Shannon, Fall River, Custer, and Pennington counties in South Dakota; Dawes County in Nebraska; Natrona, Niobrara, Converse, Weston, Johnson, and Campbell counties in Wyoming; Rosebud, Powder River, Big Horn, Carbon, and Carter counties in Montana (**Table**



**Figure 3.** Range of *Astragalus barrii*. Each point on the distribution map may represent more than one occurrence.

1). Approximately 75 percent of the known *A. barrii* occurrences are located in the Powder River Basin (**Table 1**).

A population can be defined as “a group of individuals of the same species living in the same area at the same time and sharing a common gene pool or a group of potentially interbreeding organisms in a geographic area” (National Oceanic and Atmospheric Administration 2004). Sub-populations are therefore genetically related and interact either through pollination or seed dispersal. Ideally, it is most useful for conservation planning purposes to understand spatial distribution in terms of populations as so defined. However, this concept of population cannot be applied when the genetics of a taxon, seed dispersal characteristics, and reproductive biology are not known. A less restrictive definition of population is that it is “a group of individuals of the same species that occurs in a given area” (Guralnik 1982). Since the genetics of *Astragalus barrii* and the interactions between patches of individuals are unknown, this definition also applies to the term occurrence as used in this report. In this report, an occurrence includes plants in large areas of land where there are contiguous stretches of apparently suitable, or potential, habitat (NatureServe 2005). There are usually several sub-occurrences within any given occurrence (**Table 1**; Wall Ranger District occurrence data sheets; Muenchau et al. 1991a, Hoy et al. 1993a, 1993b, 1993c, Montana Natural Heritage Program 2003, South Dakota Natural Heritage Program 2003, and Wyoming Natural Diversity Database 2003). Therefore, plants in contiguous sections on topographic maps are often combined to form one occurrence. However, some of the designated occurrences (**Table 1**) are still in very close proximity to one another and in some cases a reported occurrence in **Table 1** may be more accurately described as a sub-occurrence. If it turns out that sub-occurrences do not interact and remain genetically isolated, then it may be correct to subdivide the existing occurrences in the future. Essentially, there is insufficient information to make a critical delineation at the current time. Element occurrence delineation in **Table 1** has mostly followed that proposed by the records of the Montana Natural Heritage Program (2003), South Dakota Natural Heritage Program (2003), and Wyoming Natural Diversity Database (2003). In cases where additional records from herbaria or the literature have been found, a record was merged with an existing record if it appeared to be at the same location. Alternatively, if the record was in an apparently unique location, it was given a new arbitrary occurrence number. Occurrence delineation is likely to

change when the extent of the interaction between sub-occurrences is known.

A significant consideration in accurately counting occurrence numbers is the sympatry of *Astragalus barrii* with vegetatively similar taxa. Several of the occurrences that were located when plants were vegetative need to be confirmed during flowering to confirm that all individuals at the occurrence were *A. barrii* (**Table 1**). Similarly, it was frequently observed at reported occurrences of *A. barrii* that many individuals were not flowering. The percentage of those plants that may have been misidentified as *A. barrii* is unknown, and therefore the size of the occurrence may have been over-estimated.

*Astragalus barrii* is known from approximately 46 occurrences in Wyoming, approximately 27 occurrences in South Dakota, and approximately 35 occurrences in Montana (**Table 1**). There are less than three occurrences in northwestern Nebraska, none of which are on National Forest System land (Muenchau et al. 1991a, Weedon personal communication 2004). Occurrence information has been obtained from the Wyoming Natural Diversity Database (2003), the Montana Natural Heritage Program (2003), the South Dakota Natural Heritage Program (2003), from herbarium specimens, and from the literature (**Table 1**). Twelve occurrences are within the administrative boundaries of the Thunder Basin National Grassland in Wyoming (Heidel 2004). Four of these occurrences are, at least partially, on inholdings and thus managed by the state or are privately owned (**Table 1**). Sixteen occurrences are within the Buffalo Gap National Grassland in South Dakota (**Table 1**). USFS Region 2 manages both national grasslands. In Montana, eight occurrences have been reported from the Custer National Forest, which is part of USFS Region 1. Where possible, the land ownership or management agencies are listed for each occurrence in **Table 1**.

It is important to note that the total distribution area of *Astragalus barrii*, as opposed to occupied habitat, is generally extensive. For example, in the Railroad Buttes area (occurrence SD-6 in **Table 1**) the majority of the 2,300 individuals counted at one sub-occurrence were found in an area of “300m by 200m” (984 feet by 656 feet) and were absent from several other areas within the section surveyed that looked to have suitable habitat (Muenchau et al. 1991a). The sizes of populations and subpopulations also differ widely in all parts of the species’ range. In southeastern South Dakota, there were only four and 67 individuals counted in two (sub)

populations respectively (occurrence SD-18 in [Table 1](#)), whereas more than 4,500 individuals make up the colony at Limestone Butte (occurrence SD-1 in [Table 1](#); Muenchau et al. 1991a, 1991b). In Montana, only six plants were found in two subpopulations (occurrence MT-7 in [Table 1](#)) compared to over 3,000 individuals distributed along a length of rimrock (occurrence MT-19 in [Table 1](#)).

On the Buffalo Gap National Grassland in Region 2, estimates or counts of *Astragalus barrii* plants have been made in two large areas, the Railroad Buttes area and the Scenic Basin. Over 40,600 individual plants were counted and/or estimated in 1991 within six sections (3,840 acres [1,554 ha]) in the Railroad Buttes area (Muenchau et al. 1991a). Using plot frames along transects in selected occupied areas, the total estimated number of plants ranged from approximately 3,500 to 115,700 per acre (8,750 to 289,250 per hectare) in the Scenic Basin area in 1993 (Schmoller 1993). Assuming an average of 31,426 individuals per acre (78,565 per ha), it was estimated that there were approximately 12.8 million individuals in the estimated 407 acres (165 ha) of occupied habitat within a total area of 2,372 acres (960 ha) (see Monitoring section for further discussion).

*Astragalus barrii* has a patchy distribution and is not always found in areas defined by observers as potential habitat. In the Badlands National Park, a deductive habitat similarity model developed specifically for that area found that although 44 percent of the park comprised habitat very similar to the habitat in which *A. barrii* is found, only a small portion of that habitat was actually occupied by *A. barrii* (Dingman 2005). It is also important to note that potential habitat in much of its range has not been critically defined, and may only be loosely described as that habitat that from somewhat casual observation appears to be suitable for the species but is not occupied by it. The definition of potential habitat varies according to geography (see Habitat section). Considerable areas of potential habitat in all states within the range of *A. barrii* have been surveyed without finding plants (Schassberger 1988, Muenchau et al. 1991a, Schmoller 1993).

The clustered aspect of the distribution of the occurrences throughout the four states in which *Astragalus barrii* is found suggests that there may be a limited number of extensive meta-populations. A meta-population is defined as being composed of populations, which may be composed of smaller sub-populations, that are likely to interact in some way, for example sharing pollinators and thus exchanging genetic material. The presence of very large meta-populations

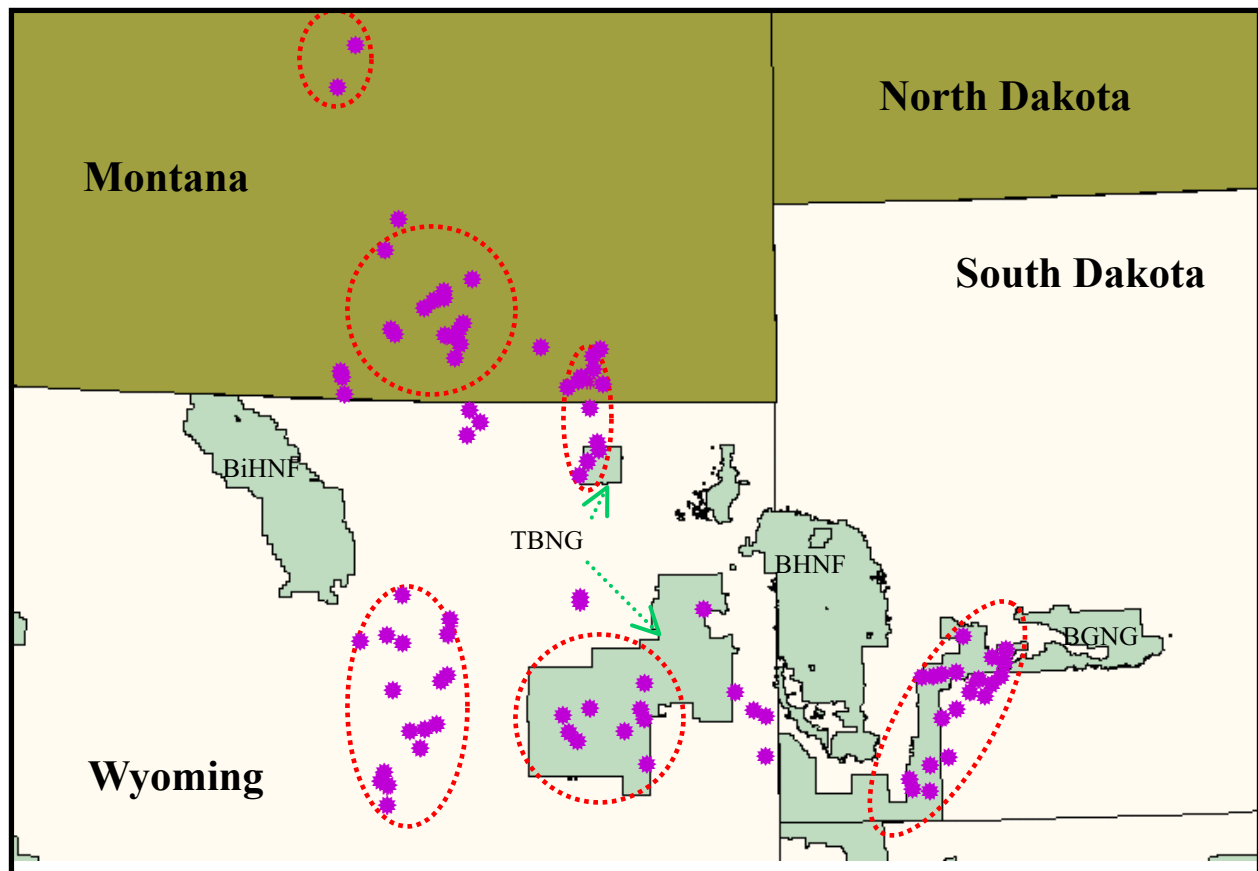
and the different genetic resources they represent have implications in potential management priorities (Frankel et al. 1995). The map in [Figure 4](#) indicates the clustered distribution of the known occurrences. Any and all of the cluster-delineations that have been suggested in [Figure 4](#) may be subdivided or enlarged in the future as more information is gathered.

#### Population trend

There are insufficient data in the literature, associated with herbarium specimens, or in the NatureServe (2005) network of natural heritage programs to accurately determine the long-term trends for *Astragalus barrii*. It has been recognized as a distinct taxon only since 1956, and information on its historical abundance is scant (Barneby 1956, 1964). Since *A. barrii* was first recognized, several large populations that appeared to be stable have been located.

Relatively few specific sites appear to have been revisited. In general, revisits to known occurrences seem to have found additional colonies, rather than relocating the original colony. This is true on National Forest System lands in Region 2. In 1991, 4,447 individuals were observed in the Scenic Basin on the Buffalo Gap National Grassland (Schmoller 1993). In 1993, the estimate was considerably higher, with over 12 million individuals estimated to be growing within the Scenic Basin area (Schmoller 1993). In 1993 considerably more land was surveyed and more colonies were found. The figure of 12 million was extrapolated from the sampling of a limited number of quadrants and is statistically questionable. Different estimates can be obtained according to the assumptions made about the area occupied and also from the way that the data are analyzed (see Inventory discussion in the Management of *Astragalus barrii* in Region 2 section). When additional colonies appear to be contiguous with an existing population, they are subsequently considered to be part of the original occurrence record. However, because the original occurrence was not relocated, it is not always clear if the new observation indicates an actual increase in the numbers of plants or just a spatial change in the population. That is, it is unknown if there are a greater number of plants within an occurrence or if colonies merely shift and the abundance remains the same.

Substantial numbers of dead *Astragalus barrii* plants have been recorded at several of the occurrence sites: SD-3 and SD-9 on the Buffalo Gap National Grassland Region 2 (Muenchau et al. 1991a), occurrence WY-42 in Wyoming and occurrences MT-28, MT-29, and MT 39 in Montana ([Table 1](#)). How the presence of



**Figure 4.** A map that illustrates the clustered distribution of the known *Astragalus barrii* occurrences across its range. National Forest System land (Region 2): TBNG, Thunder Basin National Grasslands; BGNG, Buffalo Gap National Grasslands; BHNF, Black Hills National Forest; BiHNF, Bighorn National Forest.

dead plants relates to the vigor and sustainability of the population is unknown. Because death is a natural part of the any individual's life cycle, the casual observer might assume that the presence of dead plants is normal and that the number of dead individuals observed is no cause for concern. On the other hand, dead plants may indicate that the population is experiencing an abnormal or irreversible decline. The potentially cyclical nature of death and recruitment of plants can only be speculated upon because there has not been long-term systematic monitoring. The length of time that the plants have been dead and the period of time over which the deaths occurred are additional factors to consider in evaluating the significance of die-off. Woody plant material is slow to break down in semi-arid environments. However, the windy conditions and highly erodible soils in which it grows suggest that remnants of *A. barrii* plants may be difficult to detect after a short period of time at occurrences on exposed ridges and slopes. Determining the cause of death is an important first step to understanding the potential consequences of die-off. Subsequent observations to determine if the loss was

permanent or whether individuals were replaced would generate even more valuable information on which to evaluate the significance of the die-off. Schassberger (1990) speculated that prolonged drought was the cause of the mortality at the Montana sites.

Some habitat has been lost to resource development activities in the past century, and in some cases specific populations have been impacted. Heidel and Fertig (2003) reported that one population in Wyoming is possibly extirpated. Part of one population was believed lost due to bentonite mining in Wyoming (Marriott 1992). Also in Wyoming, the expansion of a coal mine destroyed one entire population on private land while another coal mine may have impacted a second population (Marriott 1992, Wyoming Natural Diversity Database 2003). Occurrence WY-21, which was formerly on National Forest System land, is located on private land within the boundary of a mine and may no longer be extant (**Table 1**). *Astragalus barrii* has not been relocated in Carter County in Montana (occurrence MT-6 in **Table 1**) even though a total of 65 sections

were surveyed around the historic Ekalaka site reported by Barneby (1964). Also in Montana three occurrences, MT-3, MT-4, and MT-24, were considered threatened, and it was suggested that they may be eliminated in the future (Schassberger 1990). At occurrence MT-16 (**Table 1**), approximately 600 individuals were observed in 1988, but only 50 individuals were reported in 1995. There is no information to indicate if the reduction in number was due to a loss of plants or attributable to a smaller area being surveyed during the second visit. The significance of occurrence extirpation on genetic richness is unknown. Except for occurrence WY-21, no large-scale losses of plants due to human activities have been reported on National Forest System land in Region 2.

### Habitat

*Astragalus barrii* grows on dry badlands and semi-barren slopes with low vegetation cover. It grows on soils derived from shale, sandstone, silts and limestone. It typically occurs on rocky prairie breaks, ridges, knolls, and slopes (Schmoller 1995). It was found on sandstone bluffs in Wyoming (Roberts 1977). The habitat is usually described as badland or badland-like. Vegetation in this environment tends to be adapted to high insolation, considerable run-off, and exposure to sediments and salinity from exposed and partially modified geological material (Brown 1971).

Specific geological formations on which *Astragalus barrii* plants have been found include those of the Chadron formation, the Brule formation, the Rockyford Ash Member of the Sharps formation in South Dakota (Schassberger 1988, Hoy et al. 1993a, 1993b, Schmoller 1993), and the Cody shale formation and the Wasatch formation in Wyoming (Love and Christiansen 1985). *Astragalus barrii* is invariably on soils derived from the Midway-Elso formation association in Montana (Montana Natural Heritage Program 2003). Apparently, *A. barrii* is not tolerant of highly saline conditions (Schmoller 1993). *Astragalus barrii* is frequent along the Powder and Little Powder rivers that are mainly calcareous silt loams and silty clay loams of the Elso-Midway-Thurlo association (Heidel et al. 2002). There are contradictory reports with respect to the occurrence of *A. barrii* on Pierre-Samsil clay in South Dakota (Muenchau et al. 1991a, Schmoller 1993).

Therefore, *Astragalus barrii* does not appear to be restricted to a particular geologic stratum but is most likely restricted to a particular combination of soil characteristics. Schassberger (1988) suggested

that the acidity or alkalinity of soil might be important. She reported that soils tested at two of the sites in Montana were fairly alkaline, having a hydrogen-ion concentration (pH) of approximately 8. This high pH would apply to other sites in Wyoming and South Dakota where *A. barrii* has been found on calcareous soils (Heidel 2004). Schmoller (1993) remarked that *A. barrii* appeared excluded from Cedarpass soils that have pH values of approximately 6.1 in South Dakota. These soils also had higher fertility and better drainage than the adjacent badland soils where *A. barrii* grew. The Chadron formation on which *A. barrii* is predominately found in South Dakota (Region 2) is almost entirely fluvial, although carbonates are locally abundant but discontinuous and are likely associated with at least some of the known occurrences (Evans and Welzenbach 2000). In Badlands National Park, South Dakota, *A. barrii* was found most frequently in silty clay, silty clay loam, and silt loam textured soils that were slightly to strongly alkaline with a pH ranging from 7.5 to 8.5 (Dingman 2005). During the same study in Badlands National Park, paired soil pits were dug in areas occupied by *A. barrii* plants and also in seemingly identical, but currently unoccupied, habitat located nearby (Dingman 2005). No notable differences in soil characteristics were found between the sites with *A. barrii* and those sites without *A. barrii* (Dingman 2005). The location description of the occurrences and geology/soil maps available do not permit critical examination of the soil conditions at each occurrence (**Table 1**). The information available suggests there is a strong association between *A. barrii* and calcareous soils, although it does not appear to have ever been classified as a calcicole. Alternatively, or in addition, the soils on which it grows may share chemical or structural characteristics that are not immediately obvious. An example of a perhaps obscure link between the geology of widely different regions is that populations grow, and will likely be impacted, by surface mining of bentonite in Wyoming and zeolite in South Dakota (Heidel and Fertig 2003). Zeolite and bentonite are both natural aluminosilicates, which exhibit unique adsorption and ion exchange properties (Kovatcheva-Ninova et al. 2002).

On the Chadron formation, on the Buffalo Gap National Grassland (Region 2), several observations have been made on the apparent association between abundant surface chalcedony and the presence of *Astragalus barrii* (Muenchau et al. 1991a, Schmoller 1993, Dingman personal communication 2003). Chalcedony is a cryptocrystalline variety of silica dioxide, or quartz (Bates and Jackson 1984). Plants were observed to be associated with fractures in the

chalcedony where water accumulated (Dingman personal communication 2003). Schmoller (1993) suggested that the chalcedony provided habitat stabilization on steep slopes.

*Astragalus barrii* grows at elevations between approximately 1,097 and 1,737 m (3,600 and 5,700 feet) in Wyoming (Heidel and Fertig 2003), between approximately 905 and 1,268 m (2,968 and 4,160 feet) in Montana (Barton and Crispin 2003, Montana Natural Heritage Program 2003), and between approximately 274 and 853 m (900 and 2,800 feet) in South Dakota (estimates using information from South Dakota Natural Heritage Program 2003). Plants of *A. barrii* grow on slopes of various inclines, from approximately level to at least 70 percent (Schassberger 1990, Muenchau et al. 1991a). In Montana, two slope categories were defined within the Midway-Elso associations, 8 to 35 percent and 35 to 70 percent (Montana Natural Heritage Program 2003), and *A. barrii* has been found on slopes in both classes. *Astragalus barrii* has also been reported to grow on slopes facing all aspects. In Wyoming, more plants have been reported to occur on north- and east-facing aspects (Heidel and Fertig 2003). In Wyoming, plants are restricted to upper- and mid-slope topographic positions (Heidel and Fertig 2003). This seems generally, but not universally, applicable to populations in South Dakota (Muenchau et al. 1991a, Hoy et al. 1993a, 1993b, 1993c, Schmoller 1993). Although plants have been found in partially shaded habitat in Montana, the light exposure has generally been described as “open” and the plants experience high light levels. See **Table 1** for additional details of occupied habitat.

Flash floods are common in badland environments due to the intense nature of thunderstorms and the slow infiltration of the clay-rich soils. In addition, the drying and wetting cycles cause the clay-rich soils to expand and contract. These conditions promote erosion and typically prevent plant establishment (Ode 1988, Knight 1994). Because of these harsh environmental conditions, the unproductive soil properties, and occasional natural disturbance, typical successional development may be curtailed. The communities in which *Astragalus barrii* has been found may thus represent a “climax” condition, where “climax” is applied to a community that is in a state of equilibrium with its environment and does not develop further within a historic time period.

Most typically, the vegetation communities in which *Astragalus barrii* is found include sparsely vegetated grasslands, sagebrush-grasslands, or, less commonly, saltbush-grasslands. It is also associated with a sparsely vegetated understory of scattered pine

and juniper in Montana and, more rarely, in Wyoming. *Astragalus barrii* usually occupies thinly vegetated patches between stands of other plant species. Brown (1971) formally identified seven types of shrublands and woodlands in the Powder River Breaks of southeastern Montana, which extend into northern Wyoming (Knight 1994). He described *Sarcobatus* (greasewood), *Atriplex-Artemisia* (shadscale-sagebrush), *Artemisia-Atriplex-Agropyron* (big sagebrush-shadscale-western wheatgrass), *Artemisia-Agropyron* (big sagebrush-western wheatgrass), *Rhus-Agropyron* (skunkbush sumac-western wheatgrass), *Juniperus-Agropyron* (juniper-western wheatgrass), and *Pinus-Juniperus* (Ponderosa pine-juniper) communities. Soil pH was over 7.5 in all those community types but was highest (pH 7.6 to 8.3) in the *Artemisia-Atriplex-Agropyron* community (Brown 1971). *Astragalus barrii* appears to be excluded from greasewood-dominated communities, but occurrence information has listed associates that are represented in all of the other community types. However, these communities often lack distinctive boundaries, which may explain the difficulty in critically defining the *A. barrii* community types from the occurrence record information.

Within an area occupied by *Astragalus barrii*, bare ground was usually estimated to be 50 percent or higher (cover 50 percent or lower). In South Dakota, on the Buffalo Gap National Grassland of Region 2, *A. barrii* has been described as a dominant element of the community in the springtime (Hoy et al. 1993c). Associated plant species are listed in **Table 2**. This is not an exhaustive list and represents only the observations that were made on herbarium sheets, on USFS data sheets (Erk personal communication 2003), in the literature (Roberts 1977, Schassberger 1988, Muenchau et al. 1991a, 1991b), and from information provided by the Montana Natural Heritage Program (2003), the South Dakota Natural Heritage Program (2003), and the Wyoming Natural Diversity Database (2003). There are several references to associated lichens, but the species were not identified and any relationship to a microbiotic soil crust has not been reported. *Astragalus barrii* grows with at least five other species of *Astragalus*, including *A. gilviflorus*, *A. hyalinus*, *A. bisulcatus*, *A. racemosus*, and *A. spatulatus* (Roberts 1977). The taxon is often sympatric with *A. gilviflorus* var. *gilviflorus* and *A. hyalinus* (Roberts 1977, Wyoming Natural Diversity Database 2003, Heidel 2004).

Habitat information for where a taxon is typically absent, in contrast to where it grows, is often unavailable. However, such information can be very useful when evaluating an area for its potential to support a rare

**Table 2.** Plant species reported to be associated with *Astragalus barrii*. Where genus and species were reported, the names are in accordance with those published in Dorn (2001). Where appropriate, the name of the species as it was originally reported is given in parentheses.

State	Taxon
MT	<i>Achnatherum hymenoides</i> (reported as syn. <i>Oryzopsis hymenoides</i> )
SD	<i>Agropyron</i> sp.
SD	<i>Allium</i> sp.
MT, SD	<i>Allium textile</i>
MT	<i>Artemisia frigida</i>
MT	<i>Artemisia longifolia</i>
WY	<i>Artemisia pedatifida</i>
WY	<i>Artemisia</i> sp.
WY, MT	<i>Artemisia tridentata</i>
WY	<i>Artemisia tridentata</i> ssp. <i>wyomingensis</i>
MT	<i>Astragalus bisulcatus</i>
MT	<i>Astragalus hyalinus</i>
MT, SD	<i>Astragalus gilviflorus</i>
SD	<i>Astragalus racemosus</i>
WY, MT, SD	<i>Astragalus spatulatus</i>
WY	<i>Astragalus</i> sp.
MT	<i>Atriplex confertifolia</i>
MT	<i>Atriplex gardneri</i>
WY	<i>Atriplex</i> sp.
SD, MT	<i>Bouteloua gracilis</i>
MT	<i>Bromus tectorum</i>
MT	<i>Calamovilfa longifolia</i>
WY, MT	<i>Carex filifolia</i>
MT	<i>Chaenactis douglasii</i>
MT	<i>Chrysothamnus nauseosus</i>
WY	<i>Chrysothamnus</i> spp.
WY, MT, SD	<i>Comandra umbellata</i>
MT, SD	<i>Cryptantha celosioides</i>
MT, WY	<i>Cryptantha</i> sp.
SD	<i>Dalea candida</i>
WY, MT	<i>Elymus lanceolatus</i> (also reported as syn. <i>Agropyron dasystachyum</i> )
WY, MT	<i>Elymus spicatus</i> (also reported as bluebunch wheatgrass; syn. <i>Agropyron spicatum</i> )
MT, SD	<i>Elymus smithii</i> (syn. <i>Pascopyrum smithii</i> , syn. <i>Agropyron smithii</i> )
WY	<i>Erigeron pumilus</i>
MT, SD	<i>Eriogonum flavum</i>
WY, MT, SD	<i>Eriogonum pauciflorum</i>
MT, WY	<i>Eriogonum</i> sp.
SD	<i>Erysimum asperum</i>
MT	<i>Festuca idahoensis</i>
MT, SD	<i>Grindelia squarrosa</i>
MT, SD	<i>Gutierrezia sarothrae</i>

Table 2 (cont.)

State	Taxon
MT	<i>Hesperostipa comata</i> (reported as syn. <i>Stipa comata</i> )
MT	<i>Hymenopappus filifolius</i>
MT	<i>Hymenopappus polycephalus</i>
WY	<i>Hymenoxys richardsonii</i>
WY	<i>Hymenoxys</i> sp.
WY	<i>Juniperus</i> sp.
MT	<i>Juniperus scopulorum</i>
WY, MT	<i>Koeleria macrantha</i>
MT	<i>Krascheninnikovia lanata</i>
MT	<i>Lesquerella alpina</i>
SD	<i>Lesquerella ludoviciana</i>
WY	<i>Lesquerella</i> sp.
WY	Lichen (unspecified)
SD	<i>Lomatium foeniculaceum</i>
MT	<i>Lomatium</i> sp.
MT	<i>Linum perenne</i>
MT, WY	<i>Machaeranthera grindelioides</i> (also reported as syn. <i>Haplopappus nuttallii</i> and as <i>Haplopappus grindelioides</i> in WY)
SD	<i>Melilotus officinalis</i>
SD	<i>Musineon</i> sp.
MT, SD	<i>Musineon divaricatum</i>
WY	<i>Musineon</i> sp.
SD	<i>Nassella viridula</i> (reported as syn. <i>Stipa viridula</i> )
SD	<i>Oenothera caespitosa</i>
MT	<i>Opuntia polyacantha</i>
SD	<i>Opuntia</i> sp. (reported as prickly pear)
MT	<i>Oxytropis sericea</i>
SD	<i>Oxytropis lambertii</i>
WY, SD	<i>Penstemon albidus</i>
MT, SD	<i>Penstemon eriantherus</i>
MT	<i>Penstemon nitidus</i>
MT	<i>Penstemon</i> sp.
MT	<i>Phlox alyssifolia</i>
SD	<i>Phlox andicola</i>
WY, MT, SD	<i>Phlox hoodii</i>
WY, MT	<i>Pinus ponderosa</i>
MT	<i>Poa secunda</i>
MT	<i>Rhus trilobata</i>
SD	<i>Rosa arkansana</i>
MT	<i>Sarcobatus vermiculatus</i>
WY, MT	<i>Schizachyrium scoparium</i> (reported as syn. <i>Andropogon scoparius</i> )
MT	<i>Senecio canus</i>
SD	<i>Sphaeralcea coccinea</i>

**Table 2 (concluded).**

State	Taxon
MT, WY	<i>Stenotus acaulis</i> (reported as syn. <i>Haplopappus acaulis</i> )
MT	<i>Stenotus armerioides</i> (reported as syn. <i>Haplopappus armerioides</i> )
SD	<i>Tetranneuris acaulis</i> (reported as syn. <i>Hymenoxys acaulis</i> )
SD	<i>Thermopsis rhombifolia</i>
SD	<i>Toxicodendron rydbergii</i>
SD	<i>Tragopogon dubius</i>
WY, MT, SD	<i>Yucca glauca</i>
SD	<i>Zigadenus venenosus</i>
MT	<i>Zigadenus</i> sp.

plant species. Muenchau et al. (1991a) reported that there was an abrupt termination of individuals when the redness of the soil increased. They hypothesized that the redness was due to iron, which may be the cause of the exclusion. In addition, they noted that *Astragalus barrii* did not occur in some draws where *A. racemosus* was most abundant. Schmoller (1993) also observed that *A. barrii* rarely grew with *A. racemosus*. These observations suggest that *A. barrii* is excluded from selenium-rich soils since *A. racemosus* specifically grows on selenium bearing soils (Barneby 1989). The common name for *A. racemosus* is cream milkvetch (USDA Natural Resources Conservation Service 2004), but it also known locally in South Dakota as racemed poisonvetch (Schmoller 1993). Another difference between occupied and unoccupied sites in otherwise apparently suitable habitat was that there was more cover by *Helianthus annuus* (common sunflower), *Salsola tragus* (prickly Russian thistle; reported by the synonym *S. iberica*), *Melilotus officinalis* (yellow sweetclover), *Oenothera caespitosa* (tufted evening primrose), and *Pediomelum hypogaeum* var. *hypogaeum* (subterranean Indian breadroot; reported by the synonym *Psoralea hypogaea*) on unoccupied sites (Muenchau et al. 1991a).

A habitat model has been developed for populations on the Badlands National Park (Dingman 2004, Dingman 2005). The application of a habitat model to areas outside of the specific region for which it was developed should be done conservatively. The definition of potential habitat may be different according to geographic location. For example, in South Dakota, *Astragalus barrii* populations are always described as being in open areas, and Schmoller (1993) reported that *A. barrii* is seldom found on steep slopes there. In contrast, several of the known sites in Montana occur on steep slopes that are shaded for some parts of the day (Schassberger 1990). A photograph of *A. barrii* habitat

in Montana can be accessed on the internet (Locklear undated). Typical habitat in Wyoming is shown in **Figure 5**.

#### Reproductive biology and autecology

*Astragalus barrii* is a perennial that reproduces only by seed. The plant may spread only to a limited extent by vegetative growth from its branching caudex. Basal perimeters have been reported to be greater than 32 cm, 12.6 inches (Hoy et al. 1993c). *Astragalus barrii* is described as a cushion plant. Cushion plants are plants having small, hairy, or thick leaves borne on short stems and forming a tight hummock (Allaby 1992). Their meristems are close to the soil surface, which is advantageous in environmentally stressful environments (Gorsuch et al. 2001). This type of plant is classified as a hemicryptophyte according to Raunkiaer's life form system (Raunkiaer 1934).

Flowering of *Astragalus barrii* typically occurs from late April to mid-June (Barton and Crispin 2003, Heidel and Fertig 2003). Flowering is often described as peaking in May and Barneby (1964) remarked that plants only flowered in late April in years with light snowfall. In any one area, flowering time may differ according to elevation. On May 28, in South Dakota, plants at higher elevations were in bud or early flower whereas those in the draws were in late flower (Muenchau et al 1991a). A late, if not second, flowering was observed in Montana (Schassberger 1990). Plants were reported flowering on July 13, 1992 (occurrence MT-1 in **Table 1**). The observer speculated that the two weeks of rains after three months of dry conditions may have prompted this late flowering (Montana Heritage 2003). This may be important to the life strategy of *A. barrii*, because it suggests that flowering time is somewhat flexible and depends upon favorable conditions.



**Figure 5.** Habitat of *Astragalus barrii* in Wyoming. *Astragalus barrii* grows in open sites with a low vegetation cover (see text). Photographer John Proctor, Medicine Bow-Routt National Forests and Thunder Basin National Grassland.

Except for occasional observations of flower visitors, the reproductive system of *Astragalus barrii* has not been studied in detail. Based on studies of other *Astragalus* species, the flowers may be either self-pollinated, cross-pollinated, or both. Some authors have proposed that rare species have higher levels of auto-fertility and lower-levels of open pollination than those of common species (Geer and Tepedino 1993). In fact, several rare species of *Astragalus* are self-fertile and are less dependent upon pollinator activity for successful fruit set compared to some of their widespread congeners (Karron 1987a, Karron 1991). It needs to be noted that the converse is not true, and some widespread *Astragalus* species also exhibit a high degree of self-fertility. Where cross-pollination occurs, *Astragalus* species are generally insect pollinated (Geer and Tepedino 1993). Bilaterally symmetrical flowers, such as those of *A. barrii*, are frequently pollinated by medium to large polylectic bees in the genera *Bombus*, *Osmia*, and *Anthophora* (Karron 1987b). When a bee lands on the keel and inserts its head under the banner, the keel is depressed and pollen is deposited on the anterior ventral surfaces of the bee (Green and Bohart 1975). Although the bees themselves remove much of

the pollen, pollen on hairs and within crevices on the head are available for cross-pollination. Species of *Bombus* (bumblebees) have been noted as very active on some *A. barrii* occurrences, such as occurrence MT-33 in Montana (**Table 1**), and are highly likely to be pollinators. In South Dakota, three species of bees have been observed visiting flowers and were speculated to be pollinators (Muenchau et al. 1991a). Moths were also seen visiting flowers within the same population (occurrence SD-5 in **Table 1**), and in Wyoming a swallow tail butterfly was a visitor (Heidel 2004). These are unlikely pollinators because few legumes are adapted for pollination by Lepidopterans (Kalin Arroyo 1981).

The ability to self-pollinate is especially important to small populations of a species primarily pollinated by bees because bees, unlike many other flower visitors, are density-dependent foragers (Heinrich 1976). Small populations of *Astragalus barrii* with few flowers separated by relatively large distances that also have few flowering plants of any species may be pollinator limited. In addition, the size of a mat or patch may influence the frequency with which cross-pollination

occurs. Bumblebees appeared to preferentially visit large, rather than small, clumps of *A. canadensis* in an Iowa prairie (Platt et al. 1974). *Astragalus* species are recognized for their rapid development of autogamous lineages where pollinators are unreliable (Kalin Arroyo 1981). It is not clear if the harsh conditions associated with *A. barrii* habitat would contribute to unreliable arthropod populations. Studies on other rare *Astragalus* species suggest that *A. barrii* is likely, at least to some extent, to be self-pollinated although the possibility that it relies on cross-pollination cannot be discounted without further study.

The extent to which occurrences are genetically isolated depends on the method of pollination and seed dispersal. A meta-population is defined as being composed of populations that are likely to interact in some way, for example sharing pollinators and thus exchanging genetic material (see Distribution and abundance section). Spatially disjunct groups that are cross-pollinated can have high levels of dispersal and gene flow between them. Osborne et al. (1999) tracked individual bumblebees using harmonic radar and recorded that most bees regularly fly over 200 m (range 70 to 631 m [230 to 1,184 feet]) from the nest to forage even when apparently plentiful food was available nearby. Honeybees apparently can regularly forage 2 km (1.2 miles) away from their hive (Ramsey et al. 1999). In spite of the long distances traveled by bee species and the potential for cross-pollination across large areas, pollen is likely to be most efficiently transferred between neighboring *A. barrii* flowers (Harder 1990, Rademaker et al. 1997).

No information on the size of the soil seed bank of *Astragalus barrii*, the rate of its seed recruitment to the seed bank, and its seed longevity with respect to subsequent germination in the soil is available. *Astragalus barrii* seed has been successfully germinated using scarification pretreatment (Locklear 1987, Dingman personal communication 2004). Mandatory scarification is not unusual because many members of the Leguminosae have a hard, impermeable seed coat (Bewley and Black 1982). The impermeable seed coat imposes a form of physical dormancy that may confer some tolerance to unreliable environmental conditions, as well as to heat and thus wildfire (Whelan 1997). If breakdown of the seed coat is required prior to germination, it is likely that seeds can remain in the soil over at least a couple of growing seasons. The extent of seed predation is also unknown. Seed predation by arthropods can be very high amongst *Astragalus* species, and some beetle species even readily feed on *Astragalus* species that are selenium accumulators or are

otherwise toxic to livestock (Platt et al. 1974, Clement and Miller 1982, Lesica 1995). Roberts (1977) observed that predatory seed beetles, *Acanthoscelides* species (Coleoptera: Bruchidae), were commonly observed on all *Astragalus* species of *Orophaca* phalanx. Dense pubescence on the pod of *A. utahensis* prohibits some arthropod species from penetrating the pod wall and depositing eggs in the pod (Green and Palmbald 1975). However, this seems an unlikely defense mechanism for the more sparsely hairy pod of *A. barrii*.

Pods of *Astragalus barrii* dehisce from the base upwards along both, but primarily the ventral, sutures thus releasing seed (Barneby 1964). Seed dispersal mechanisms are also not known with certainty. It has not been documented whether the pods of *A. barrii* open, and thus lose some or all seed, prior to their dropping off the plant in the fall or if the seeds are retained in the pods until the latter are off the plant. The pod is deciduous and dehiscent in many sessile-flowered species of *Orophaca*, whereas it is persistent amongst pedunculate species (Roberts 1977). However, although the pod in two pedunculate species (*A. sericoleucus* and *A. aretioides*) remains attached to the pedicel, both fall off the plant before the pod opens on the ground (Roberts 1977). It has been observed that it is important for subsequent germination to collect seed at the time of natural dehiscence (Dingman personal communication 2004). Dingman observed that seeds collected in July, before pod dehiscence, were too immature to germinate, but those collected in August, after pod dehiscence, also did not germinate. This observation raises the possibility that, in addition to the physical dormancy imposed by the seed coat of *Astragalus* species (see Reproductive biology and autecology section), a physiological dormancy may be acquired during the maturation period (Baskin and Baskin 2001).

The patchy nature of the spatial distribution of *Astragalus barrii* suggests that seed dispersal may often be limited and localized around the parent plant (Roberts 1977, Schassberger 1990). Observations in South Dakota indicate that the gravity-dispersed seed typically follows water courses, and therefore water appears to be the primary dispersal agent in that region (Dingman personal communication 2004, Dingman 2005). Where seeds remain in the pod, Roberts (1977) concluded that seed dispersion of the related and sympatric *A. gilviflorus* seemed to be largely fortuitous. He pointed out that the papery, marcescent calyx associated with the pod might be suited to short distance dispersal by rolling. This applies equally to *A. barrii*, which has the same calyx characteristic (Barneby 1964). Dispersal by zoochory, such as by ants and rodents, is also likely

(Drezner et al. 2001, Veech 2001). Rodents may cache fruits, also contributing to short-distance dispersal. Given the very windy environment in which *A. barrii* grows, wind may also be effective in dispersing seed, although wind-dispersed seeds typically move only short distances (Silvertown 1987). Rare events, such as intense whirlwinds or dust devils, may move seed over considerable distances and therefore have significant impacts on a spottily distributed species.

Hybridization between *Astragalus* taxa is a rare phenomenon (Liston 1992, Spellenberg personal communication 2003). Genic or chromosomal factors may confer reproductive isolation to the taxon (Grant 1981, Liston 1992). Cross-pollination may also be avoided because some pollinators are species-specific and may not visit multiple species of *Astragalus* (Green and Bohart 1975) or because sympatric species flower at different times. For example *A. gilviflorus* is typically already in fruit when *A. barrii* is flowering (Roberts 1977). In general, there is relatively little evidence of hybridization between *A. barrii* and sympatric species. However, individuals with flower color and flower size intermediate between *A. barrii* and sympatric taxa have been observed in South Dakota and Wyoming (Dingman personal communication 2004, Heidel personal communication 2004). A recent observation was made that there appeared to be morphological intermediates between *A. barrii* and *A. hyalinus*, which generally flowers later than *A. barrii*, in the Spring Creek Unit on the Thunder Basin National Grassland Region 2 (Heidel 2004). A portion of one intermediate plant was collected as a voucher for further evaluation (Heidel collection 2281; Heidel 2004). It may be significant that Barneby (1964) reported that *A. gilviflorus* is highly variable in leaflet shape and flower size and that variants with “blue corollas, the banner hairy at the back” had been observed in Montana. The possibility that racial differentiation exists among many *Orophaca* species, including *A. barrii*, needs to be considered, especially when crafting a conservation management strategy. Morphological differences may or may not represent substantial genetic diversity. For example, different environmental conditions may cause differential gene expression. However, certain *A. barrii* populations may have become adapted to specific regions and habitat conditions, thereby becoming genetically different from one another. In this case, loss of genetic diversity would occur if certain populations were lost.

## Demography

A combination of environmental variables as well as aspects of the biology of a species may influence the

spatial distribution of individuals within a population. The spacing of *Astragalus barrii* may be influenced by the topography of the site, the presence of suitable substrates, and the availability of suitable micro-sites for seed germination and seedling establishment. In addition to habitat restrictions, the amount of seed production by individual plants and the ways by which the seed is dispersed will also affect spatial patterns (Platt et al. 1974). Population growth may be related to plant size and density (Silvertown and Charlesworth 2001). For example, if *A. barrii* is primarily cross-pollinated, large mats may be expected to produce disproportionately more seed than small clumps due to greater pollination success (see Reproductive biology and autecology section; Platt et al. 1974). In this case, smaller individuals would be expected to be denser around large mats. This hypothesis can be tested in the field.

*Astragalus barrii* has a cushion or mat-forming plant growth habit. Individual mats may be sparsely patchy to densely clustered within occurrences. In some instances two individuals will grow together to form a mat that, before closer inspection, appears to be one large individual plant (Muenchau et al. 1991a). Except in Muenchau et al. (1991a), one mat appears to be equated with one individual in *A. barrii* survey reports. Currently there is no information to determine the frequency with which independent individuals grow together to form one mat. The size of a plant is unlikely to reflect its age, especially between populations or even sub-populations of plants. Environmental conditions, for example moisture, will likely have the primary influence on plant size. Where environmental conditions are similar, mat size is also a confounding issue because it may be difficult to separate mat size from individual size during cursory surveys.

In general, reports indicate that there is a preponderance of adults in *Astragalus barrii* populations, and the absence of seedlings in the field has been particularly commented upon (Schassberger 1990). This may be ascribed to low seed production, high seed predation, low seedling survival and establishment, or a combination of all three. *Astragalus barrii* produces several fruits, but often only one seed per pod matures (Barneby 1964). Therefore, although seed availability does not appear to be a critical limitation in large populations, it may be a significant factor in small colonies. High seedling mortality may also be expected under the harsh environmental conditions in which *A. barrii* grows (see Habitat section). The importance of a protective habitat niche for seedling establishment is supported by the observation that seeds tend to germinate

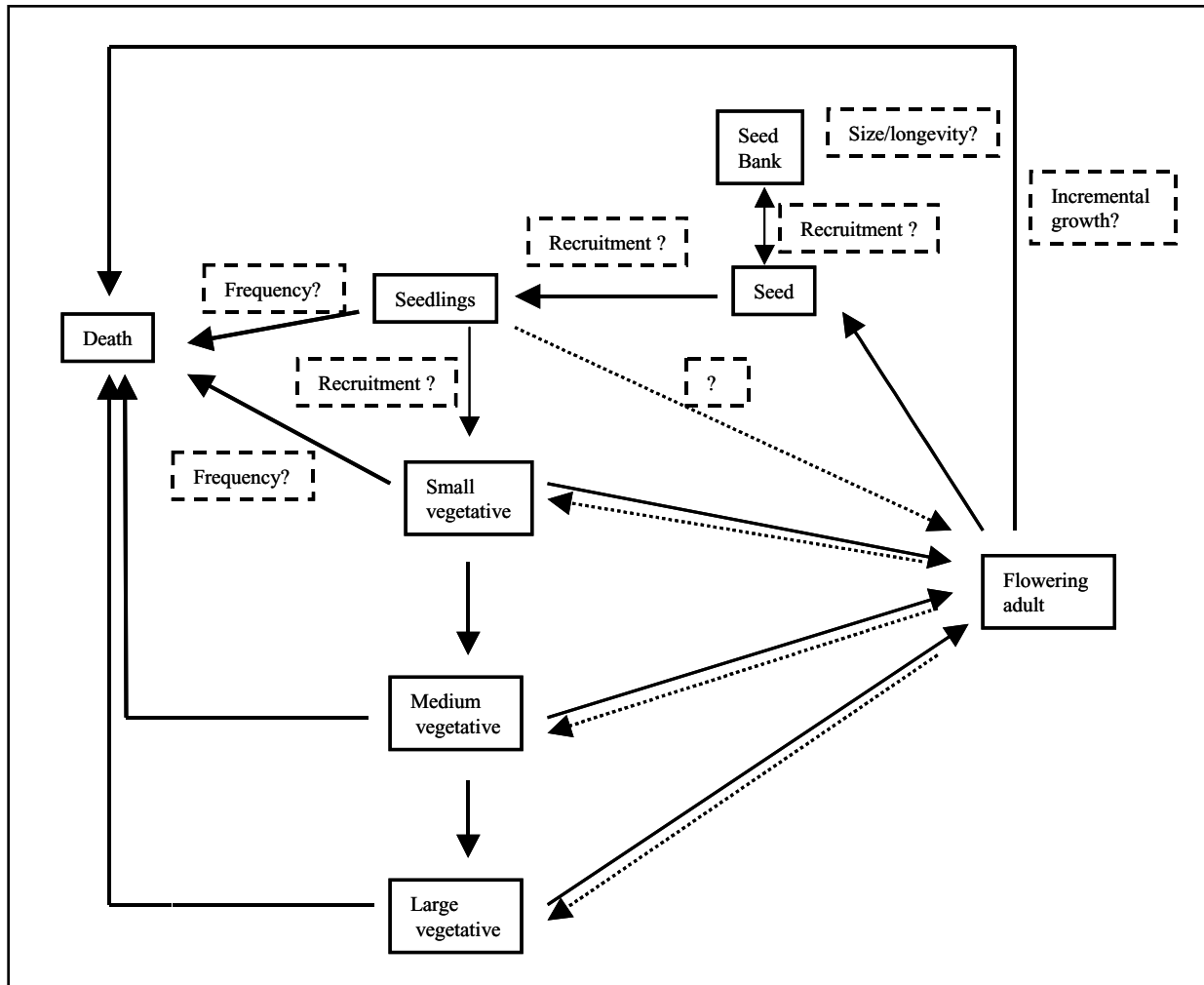
within an established mat, which could then act as a nurse plant (Muenchau et al. 1991a). In May 1991, young seedlings were found at some occurrences on the Buffalo National Grassland Region 2. These seedlings were defined as young because a woody caudex had not yet developed. Some (the percentage is not clear) young seedlings were observed intertwined in the mat of a mature plant. The fact that a portion of many of the mats observed in Wyoming (e.g., occurrence WY-42 in **Table 1**) were described as “mostly dead” suggests that younger plants may typically grow within older plants increasing mat size and making it look like a portion, rather than an individual, is dead. A fourth alternative explanation for the paucity of seedlings is that seed only germinates episodically when conditions are, in some way, most favorable. From field observations, this situation appears to be very likely (Schassberger 1990, Muenchau et al. 1991a, Hoy et al. 1993b, 1993c, Schmoller 1993, Wyoming Natural Diversity Database 2003). Seed stored in the soil seed bank may contribute to recruitment during episodic germination events.

By comparison to other taxa within the *Orophaca* phalanx, it is believed that *Astragalus barrii* individuals are quite long-lived (Roberts 1977). Field observations during a study in the Badlands National Park, supports this contention (Dingman 2005). The annual growth rate of individual plants was measured over two years. Plant growth rates are likely to vary from year to year depending upon environmental conditions, and therefore two years of data permit only limited conclusions. Using either the mean or maximum inter-annual growth rates observed in this study, the largest plant in the demography plots was estimated to be between 8 and 59 years old. Considering all plants measured in the study, plants of median size (38.5 cm<sup>2</sup> [5.97 inches<sup>2</sup>]) were estimated to be about seven years old based on the mean inter-annual growth rate (Dingman 2005). Individuals of *A. barrii* also appear to be long-lived because the mats can be on pedicels several centimeters above ground level due to erosion of the soft, surrounding soil (Schassberger 1990, Muenshau et al. 1991, Wyoming Natural Diversity Database 2003). However, the height of the pedicels may not be directly related to age because it is also the result of other mechanisms. The plants can “gather and hold the soil that blows or spatters in” (Barr 1951). Individuals of other members of the *Orophaca* have been recorded to live for 15 to over 25 years (Roberts 1977).

Members of the section *Sericoleuci*, which includes the taxa closely related to *Astragalus barrii*, tend to fruit sparingly. In contrast to this situation, Barneby (1964) remarked that *A. barrii* was unusual

amongst the *Sericoleuci* because it flowered prolifically, producing fertile pods even under cultivation. In most occurrences where reproductive state was noted, there appeared to be both vegetative and flowering individuals of approximately the same size within a population (Montana Natural Heritage Program 2003, South Dakota Natural Heritage Program 2003, Wyoming Natural Diversity Database 2003). Several reports indicate that *A. barrii* may produce few or no flowers in some years (Schassberger 1990, Muenchau et al 1991a, Hoy et al 1993b, Schmoller 1993, Heidel 2004). However, from recent studies in South Dakota, Dingman (personal communication 2004) observed that within a population, plants flowered at different times and most if not all individuals flowered during the growing season. Therefore, at the current time, it is not known with certainty if individuals that flower one year can revert to a vegetative state in one, or more, succeeding years (**Figure 6**). Asset allocation is an important facet of the survival strategy of a taxon. Flowering every year, even under unfavorable conditions, suggests that resources are directed towards producing progeny rather than towards maintaining the adult individual. In many species of long-lived perennials, assets are allocated to favor the survival of the adult, and flowering and seed production are secondary to the most important life cycle components of growth and survival of the adult plants (Silvertown et al. 1993).

Population viability analyses for *Astragalus barrii* have not been undertaken. The population size of *A. barrii* is quite variable, with reports that approximately 30 to greater than 4,000 individuals comprise a population (see Distribution and abundance section). At the present time, evidence suggests that population growth is restricted by extrinsic factors such as substrate and vegetative cover. It is clear that *A. barrii* usually exists as patches within a subdivided population. However, it is unknown if there is a balance of frequent local extinctions and colonizations within a colonized area or whether, once established, microsites are occupied for long periods of time. Dead plants were frequently observed on several occurrences on the Buffalo Gap National Grassland Region 2 in 1991, but their percentage of the total population was not reported (Muenchau et al. 1991a). Also, there were no subsequent studies to determine whether the dead plants were eventually replaced. As discussed above, the age and population structure of the *A. barrii* plants suggests that, once established, populations are quite long-lived, but this cannot be assumed without developing long-term monitoring records. The propensity to flower raises the possibility that there might be a greater turn-over of



**Figure 6.** Lifecycle diagram for *Astragalus barrii*. Dashed boxes and dotted lines indicate uncertainty with respect to the stage or the process in the life cycle of the taxon.

individuals than for other *Astragalus* species in similar habitat. This speculation is primarily derived from the fact that *A. barrii* invests a higher amount of energy into flowering and fruit production than other members of the *Orophaca* phalanx. This behavior is also in contrast to many long-lived taxa that allocate a large proportion of resources into growth and survival of the adult plants (Silvertown et al. 1993, Forbis and Doak 2004). On the other hand, some long-lived taxa also exhibit prodigious flower production, but their population growth is limited by low seed germination rates, high seedling mortality, and high variability of growth between individuals and between years (Dunwiddie et al. 2000).

Schassberger (1990) noted that there were particularly large *Astragalus barrii* mats without flowers in some locations in Montana. She speculated that it was a result of natural aging, increased canopy cover, an obscure life history pattern, or other unknown

factors. Sites on the Custer National Forest (Region 1), such as the large populations at Taylor Butte Rim area (occurrence MT-19) and King Creek Well (occurrence MT-9), are moister and support successional more advanced vegetation cover than the other occurrences (Schassberger 1990). Schassberger (1990) noted that *A. barrii* mats tended to be very large in these habitats and speculated that successional status of the habitat influences age class distribution of the species. That is, populations that have a larger number of older mats have lower rates of flowering and fruit production, which may result in reduced seedling establishment (Schassberger 1990). This is an interesting observation. The hypothesis can be tested further now that several populations with large individuals have been located in the more barren habitats of South Dakota (**Table 1**).

Population density is also likely influenced by the availability of resources. Although populations may be

large, individual colonies may be isolated and small. Harper (1977) suggested several reasons why colonies may be small. The carrying capacity of the site may be low, the available microhabitat sites may be few and separated by distances beyond the species' normal dispersal ability, the habitability of the site may be of short duration because of successional displacement, or the site colonization is in its early stages and full exploitation of the site has not occurred. In the case of *Astragalus barrii*, it is likely that the carrying capacity of the site and the relative paucity of available sites contribute to the fragmented populations. Several reports have commented upon the absence of plants in ostensibly suitable habitat (see Distribution and abundance section for definition of potential habitat) (Muenchau et al. 1991a, Schmoller 1993).

A simple life cycle model of *Astragalus barrii* has been summarized in diagrammatic terms (**Figure 6**). The steps that particularly need to be clarified are noted by “?” at the appropriate arrow, for example the frequency with which flowering plants can revert to vegetative plants in subsequent years. More information is needed to define which of the life history stages have the greatest effect on population growth and survival. The available facts suggest that *A. barrii* is a perennial species adapted to environmentally stressful conditions and maintained in established, relatively long-lived populations (Schassberger 1990, Muenshau et al. 1991, Dingman 2005). These characteristics are consistent with those of a k-selected species having a stress-tolerant life strategy (MacArthur and Wilson 1967, Grime et al. 1988).

No demographic studies of *Astragalus barrii* have been undertaken, and transition probabilities between the different stages, from seed production to the flowering adult, are unknown. Lesica (1995) used stage-based transition matrix models and elasticity analysis to elucidate the demography and effect of herbivory on *A. scaphoides*, a long-lived, tap-rooted perennial. *Astragalus scaphoides* exists as dormant rootstocks, small non-reproductive plants, large non-reproductive plants, and reproductive plants. It suffers from inflorescence predation by insects and livestock and also from insect seed predation. It experiences losses of pre-dispersal fecundity (total number of immature fruits) averaging 50 percent. Elasticity analysis revealed that population growth continues in spite of the relatively small contributions of recruitment as compared to growth and survival of non-reproductive plants and that the survival of the species in total depends little on reproduction and recruitment (Lesica 1995).

One of the management implications from this study is that disturbances that would significantly impact the adult plants would have detrimental consequences on population stability. Such a study on *A. barrii* would be very useful.

Problems associated with demographic studies and population viability analysis of *Astragalus barrii* include size being unrelated to age, multiple individuals comprising a mat, and aging measurements only being possible through destructive sampling, that is cutting through the caudex (Dingman personal communication 2004). These are problems that are difficult to overcome in short-term demographic studies. A long-term study could overcome some of these issues by following individuals in permanent plots. Even though environmental conditions undoubtedly influence plant growth rates, it would be interesting to consider the size of the mat as a function of population age, which may be a reflection of population stability. Such long-term studies would be labor-intensive but very valuable in understanding the biology of the individual and the sustainability of populations.

#### Community ecology

Interactions with native fauna, save for observations of visits by bumblebees and some Lepidoptera, have not been documented for *Astragalus barrii* (see Reproductive biology and autecology section). The Lepidopteran visitors may lay eggs on *A. barrii*, since several species of *Astragalus* act as host plants for larvae (Scott 1997). Some arthropod foragers such as Meloid beetles have been reported to have a significant impact on some populations of another sympatric and related taxon, *A. gilviflorus* (Roberts 1977). However, seed predation by arthropods is not necessarily bad at levels under which the species has evolved and may be important to long term species sustainability. In fact, in some cases they may have had an important influence on population dynamics and diversity within the genus *Astragalus* (Green and Palm bald 1975, Mancuso and Moseley 1993).

The low nutrient environment of *Astragalus barrii* habitat may be alleviated to some extent by association with nodulating bacteria. Specific associations with nitrogen-fixing bacteria have not been reported. However, since some populations of the related *A. gilviflorus* (reported as *A. triphyllus* Pursh) in North Dakota are nodulated, it is possible that *A. barrii* is also associated with nitrogen-fixing bacteria (Allen and Allen 1981). This needs to be confirmed.

*Astragalus* species in the *Orophaca* phalanx do not accumulate selenium, so they do not have the distasteful aroma typical of many *Astragalus* species, which tends to deter livestock from browsing (Roberts 1977). *Astragalus* species that are morphologically similar have been found to have similar nitro-compounds, which are sometimes particularly toxic to livestock (Williams and James 1978). Roberts (1977) also reported that orophacas specifically do not contain aliphatic nitro-compounds. This observation needs to be confirmed on a species-by-species basis because *A. sericoleucus*, another species in the *Orophaca* phalanx, does give a positive test for nitro-compounds (Stermitz et al. 1972). Since the specific structure or concentration of the nitro-compounds were not identified, the extent to which *A. sericoleucus* maybe poisonous is unknown. Herbage toxicity might also vary depending on the time of year and environmental conditions. Levels of nitro-compounds vary according to growth stage and time of year (Williams and James 1978). In addition, environmental factors such as drought can also influence the levels of nitrogenous secondary plant compounds in all parts of a plant.

*Astragalus barrii* is morphologically very similar to *A. gilviflorus*, and Fertig (1998) remarked that herbivory on this latter species is unlikely because of its low-matted morphology. Some evidence supports this hypothesis. There was only evidence of light grazing by horses (occurrence MT-26 in [Table 1](#)), and livestock apparently do not favor it in Montana (Schassberger 1990). However, observations in Montana suggest that domestic sheep are potentially damaging herbivores to *Orophaca* taxa (Vogel and Van Dyne 1966). Vogel and Van Dyne (1966) reported that domestic sheep preferred a list of forbs that specifically included *A. gilviflorus*. Species that are selected by sheep are documented to be more abundant on ungrazed land, implying that grazing negatively affects abundance (Strasia et al. 1970, Bonham 1972). Domestic sheep can also have indirect effects on bee-pollinated plant species. Sugden (1985) reported that sheep grazing in the habitat of *A. monoensis*, another perennial endemic species, endangered bee pollinators by destroying potential and existing nest sites and by removing food resources.

*Astragalus barrii* either does not colonize or flourish in highly competitive communities. It is clear that it only grows in areas with relatively sparse vegetation cover and few exotic weedy species. This is true of many *Astragalus* species. Barneby (1964) noted that the majority of *Astragalus* species occur in xeric conditions that have little competitive vegetation. Notwithstanding the sparse vegetation, a

relationship between dwarf sagebrush (*Artemisia* sp.) and some *Astragalus* species has been reported in the Intermountain West (Barneby 1964). The dwarf sagebrush provides shelter for seedlings and later protects the tender foliage from grazing animals. Considering the frequency with which *A. barrii* occurs with *Artemisia* species ([Table 1](#)), this observation may be relevant to *A. barrii*. This hypothesis can be evaluated by more field observations.

*Astragalus barrii* plants apparently are well able to tolerate a certain amount of natural soil disturbance and erosion. The length and structure of the taproot has not been studied, but they are likely to be considerable. The branching caudex and compact growth form are well adapted to catch and retain soil particles. *Astragalus barrii* plants continue to grow on soils that have been washed out and eroded, leaving the woody caudex exposed and elevated (Muenchau et al. 1991a). Schmoller (1993) suggests that disturbance is a requirement for *A. barrii* because he observed plants only at sites with evidence of soil erosion and sediment deposition on the Buffalo Gap National Grassland, Region 2. In the same area, Dingman (personal communication 2003) noticed plants follow drainage channels but do not grow in areas where water makes incised channels. Plants apparently grow in the low energy portion of the overland flow. In support of this observation, Schmoller (1993) also indicated that *A. barrii* only occurred in channels that experienced low flow and not in incised channels. These observations suggest that the low-energy flow permits more water to permeate the soil. Thus, in an otherwise dry environment, *A. barrii* favors sites with relatively more available water. This hypothesized link between more available soil-water and colonization is also supported by observations on the association between surface chalcidony and *A. barrii* occurrences (see Habitat section). As well as experiencing a moderate level of disturbance, these areas also support low vegetative cover. Therefore the low competitive environment may also substantially favor *A. barrii* establishment (see Habitat section). Barr (1951) noted that the most important factor in successfully cultivating *A. barrii* was to leave it free from competition. One observation that was made in the Railroad Buttes area on the Buffalo Gap National Grassland Region 2 was that mats appeared "healthiest" on the steeper (approximately 70 percent incline) slopes with an east-northeast aspect (Muenchau et al. 1991a). It is unknown if the distance from human-derived disturbances, the level of disturbance, the water availability, or some other environmental parameter was responsible.

When suitable substrates were available, occurrences have been reported along road cuts, along cow trails, and in semi-disturbed road banks that have received occasional off-road vehicle (ORV) use, suggesting that the species is tolerant of non-environmental disturbance and/or capable of re-colonizing disturbed sites (Proctor personal communication 2004). Schmoller (1993) reported that recently trampled individuals appeared “to suffer no ill effects” but did not elaborate on the type or extent of the trampling. Repeated trampling is likely to physically break plants and to ultimately destroy them. Also, there is no information on the long-term impact of trampling, which may result in soil compaction and/or erosion. Essentially, the persistence of a taxon per se is not proof that the taxon is unaffected by an activity. A decrease in reproductive output and/or a change in the belowground population size are both potential reactions that are not considered in a simple observation of persistence. Plants appear to grow along vehicle tracks (**Figure 5**). They have also been observed actually within vehicle tracks in South Dakota (Dingman personal communication 2004). In this case, the tracks were used periodically, usually by range managers to supply winter-feed to livestock. The timing of use may be important. The ground is hard in the winter, and the plants are dormant. Therefore, the potential growing points are likely to be partially protected. Another consideration is that the tracks may act as low-energy water channels, as discussed above. It would be useful to establish when plants colonize the tracks and to compare how long they remain in tracks under various levels of use. Where recreation vehicle trails go through the colonies at Railroad Butte, no, or at least very few, *Astragalus barrii* were found in the tracks (Muenchau et al. 1991a). There is little other specific information on the subject, but plants are unlikely to become established or to persist on regularly bladed roads or in ORV vehicle tracks that receive continual use. This is because even though *A. barrii* may persist at disturbed sites or behave as a pioneer species, it does not seem to have the life strategy characteristics or the competitive ability of a typical ruderal species (see Demography section).

The role of fire, another form of disturbance, in maintaining *Astragalus barrii* populations is undocumented. The typically low levels of litter accumulation in its native habitat suggest that in pre-colonial times, *A. barrii* was only infrequently exposed to fire, and those fires were likely of low intensity whereby the heat of the fire does not penetrate the soil and some of the vegetation survives (Brown and Smith 2000). In fact, the low vegetation cover suggests that the areas in which *A. barrii* occurs may act as refugia from

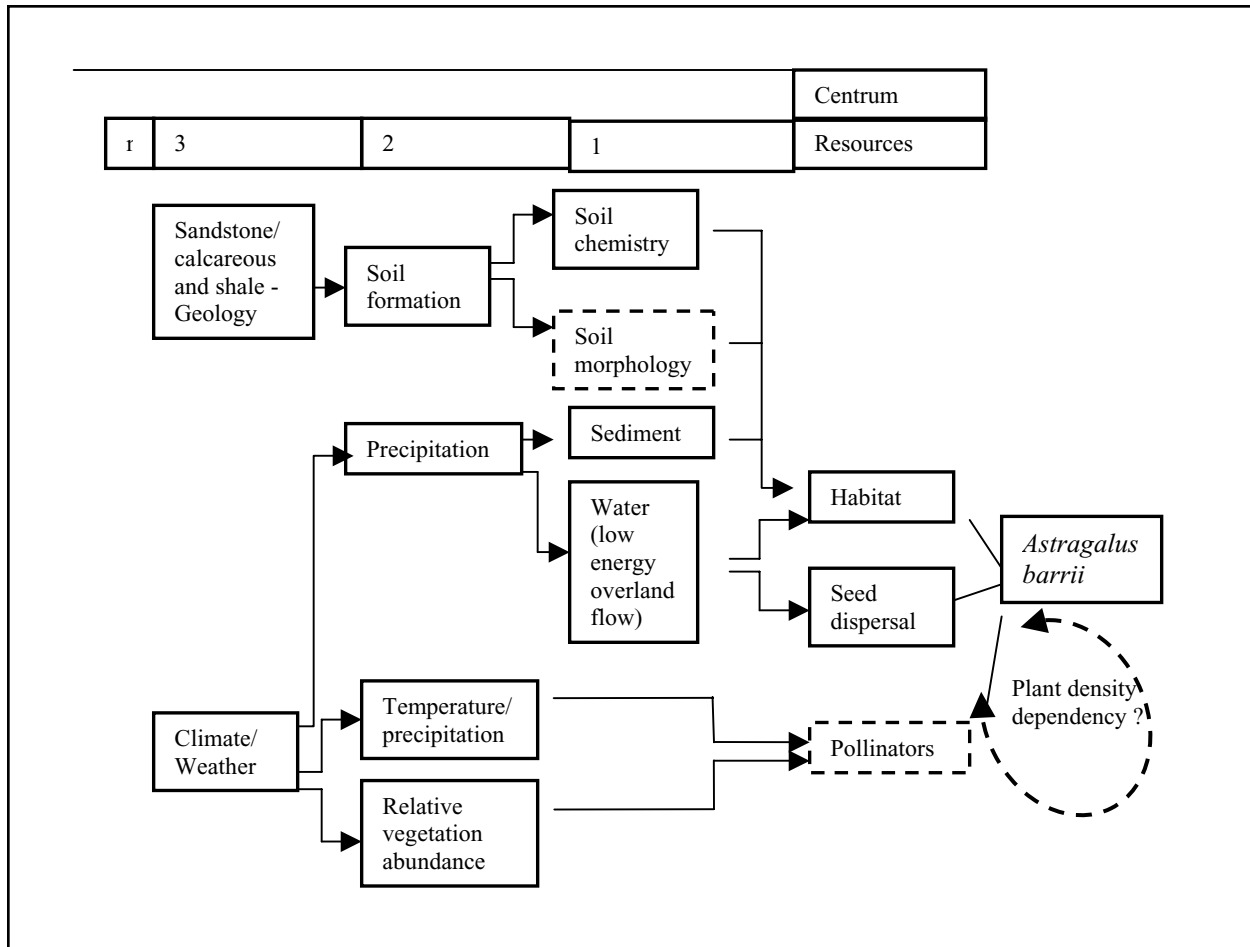
high intensity fires at the landscape level. Therefore, the historical fire regime of areas surrounding *A. barrii* habitat may be quite different to that of its habitat. *Astragalus barrii* was found at a site on the Custer National Forest (Region 1; occurrence MT-19 in **Table 1**) that had burned nearly 20 years previously in a generally broad area. However, since the immediate habitat of *A. barrii* in this area had not burned during more recent fires on the forest (Schassberger 1988), it is not possible to judge how the plants, and the dynamics of the population, directly responded to fire.

An envirogram is a graphic representation of the components that influence the condition of a species and reflects its chance of reproduction and survival. Envirograms have been used especially to describe the conditions of animals (Andrewartha and Birch 1984) but may also be applied to describe the condition of plant species. Those components that directly impact *Astragalus barrii* make up the centrum, and the indirectly acting components comprise the web. Unfortunately, much of the information to make a comprehensive envirogram for *A. barrii* is unavailable. The envirogram in **Figure 7** is constructed to outline some of the components known or speculated to directly impact the species. The dotted boxes indicate resources that are likely but not proven. Resources include soils derived from specific geological formations although the basis for the preferential colonization of one soil over another is not clear. Water is a resource because it provides suitable habitat and is involved in seed dispersal. Non-specific pollinators have been included, but they are speculative because the degree to which selfing, or the reliance on cross-pollination, occurs in *A. barrii* is also unknown. Other than low-energy water flow and sediment generation, disturbance per se has not been included in the envirogram because the types that are beneficial are not well understood. Natural disturbance, such as that caused by rodents and rainstorms, and human-induced disturbance, such as that caused by all terrain vehicles, have vastly different consequences. Precipitation appears to be a defining variable.

## CONSERVATION

### *Threats*

Existing and potential threats to some *Astragalus barrii* occurrences include activities associated with resource extraction, some recreation activities, urbanization, grazing, and an increase in the abundance of invasive weeds within its habitat. Potential threats might also include global climate change and



**Figure 7.** Envirogram of the resources of *Astragalus barrii*. The dashed line indicates the resource is unconfirmed and requires verification.

environmental, demographic, and genetic stochasticity. Each subject is discussed in more detail in the following paragraphs. Not every occurrence is currently exposed to all the threats or even equally vulnerable. However, the natural environment is, by nature, a dynamic system, and also land use needs change. Threats that are not currently a concern on National Forest System land need to be considered as management practices and land use policies are altered. The extent to which each threat is currently a concern on National Forest System land has been noted in the appropriate paragraphs.

Populations were reported to be threatened by the expansion of surface mines for bentonite in Wyoming and zeolite in South Dakota (Heidel and Fertig 2003). Some populations may have been impacted by coal mining in Montana and by oil and gas development in both Montana and Wyoming. Schassberger (1990) and Marriott (1992) reported that several occurrences are on, or adjacent to, land being strip mined for coal and suggested that the populations will eventually be

eliminated as the mines expand. The present activities related to resource extraction are localized and do not appear to be perceived as significant threats at the current levels. However, it seems likely that the Powder River Basin, where the plants occur in Wyoming and Montana, may experience considerable loss of *Astragalus barrii* habitat in the future (EPCA Interagency Team 2000), and the potential threat from coal bed methane development in both Wyoming and Montana appears to be significant.

Extractable resources are very abundant in the Powder River Basin and have yet to be fully developed. The Powder River Basin area is a 22,000 square mile (56,980 sq km) basin in northeastern Wyoming and southeastern Montana; approximately 75 percent of the basin is in Wyoming (Taber and Kinney 1999, Crockett 2001). The Powder River Basin is estimated to contain more than one trillion tons of coal, plus extensive deposits of oil, natural gas, and uranium (Crockett 2001). Coal bed methane is currently the most

important resource in the Powder River Basin. In 2001, the coal bed methane play in the Powder River Basin of Wyoming was the most active “natural gas play” in the United States (Crockett 2001). The Potential Gas Committee estimated that the recoverable coal bed methane resources are 24 trillion cubic feet, but the cumulative coal bed methane production through March 2001 is only 0.36 trillion cubic feet (Crockett 2001). Parts of Powder River and Big Horn counties have the majority of *Astragalus barrii* in Montana. They also have the highest probability for significant reserves of coal-bed natural gas in Montana (Wood and Bour 1988, Bales 2002). Coal bed methane development is also currently being aggressively pursued in the Powder River Basin of Wyoming (Carroll personal communication 2003, Wyoming State Geological Survey 2003). Most of the public lands managed by the BLM in the range of *A. barrii* are open to oil and gas leasing and mineral development. The WY-30 occurrence (**Table 1**) that was observed in 1979 and again in 1991 is one specific example of an occurrence on BLM public land that might be affected by resource exploration and development. Another example is occurrence WY-6 (**Table 1**) that is located at Notches Dome in Wyoming (Citation Oil & Gas Corporation 2005). *Astragalus barrii* was also in Parcel #282 that was in the State of Wyoming’s oil and gas lease auction in 2002 (Board of Land Commissioners 2002). The current status of this population is unknown.

Habitat loss does not result only from the disturbance caused directly by well pad installation, mine expansion, and exploration activities, but also from roads, power lines, and other installations that must be established as part of the development infrastructure. In 1998, the Dakota, Minnesota & Eastern Railroad Corporation (DM&E) filed an application with the Surface Transportation Board seeking to construct and operate a new rail line and associated facilities, which would provide an extension of DM&E’s existing rail lines into the Powder River Basin coal fields in Wyoming (Surface Transportation Board 2005a). The action involves the proposed construction of approximately 280 miles of new rail line and the rehabilitation of approximately 600 miles of existing rail line in Wyoming, South Dakota, and Minnesota (Surface Transportation Board 2005a). The new rail line will travel across the habitat of *Astragalus barrii* in Wyoming and western South Dakota. The existing rail line west of Wall, South Dakota also passes through *A. barrii* habitat (Surface Transportation Board 2005a). This construction project is likely to cause significant disturbance, but the impacts to specific occurrences of *A. barrii* can not be evaluated with

the information available. The DM&E Railroad Draft Environmental Impact Statement (EIS) mentioned that the Forest Service, the BLM, and “botanical experts” would examine the potential impacts to *A. barrii* (Surface Transportation Board 2005a). Potential impacts to *A. barrii* were not specifically described in the DM&E Final or supplemental EIS documents because Biological Assessments were only reported for taxa with status under the Endangered Species Act (Surface Transportation Board 2005c; see Management Status section). The Forest Service will issue a special use permit for DM&E operations on National Forest System lands, which includes provisions to conserve species designated as sensitive (Roche personal communication 2006). A Final Supplemental Environmental Impact Statement, which includes final conclusions and recommendations, was completed on December 30, 2005 (Surface Transportation Board 2005a). It is anticipated that the Surface Transportation Board and cooperating agencies will issue their decisions on DM&E’s proposed project in early 2006 (Surface Transportation Board 2005b).

The Final Environmental Impact Statement for the Land and Resource Management Plan for the Thunder Basin National Grassland, Region 2, it notes that none of the existing populations of *Astragalus barrii* occur within Management Area 8.4, which are areas slated for mineral production and development (USDA Forest Service 2002c). However, there are some occurrences that appear to be within the sphere of influence of mineral and resource development. Specifically on the Thunder Basin National Grassland in Region 2, the land including occurrence WY-21 (**Table 1**) has been relinquished by a development company, but the section in which it occurs is surrounded by land leased for development (USDI Bureau of Land Management 2003b). Similarly, the sections containing occurrences WY-12 and WY-13 (**Table 1**) do not apparently have any development scheduled although they are near mining leases (USDI Bureau of Land Management 2003b). Some disturbance may be expected across occurrence WY-13 since the section is between a road and railroad tracks. Occurrence WY-12 is bound on two sides by roads and is within 2 miles (3.2 km) of a substantial mining lease.

Areas in which *Astragalus barrii* occurs in South Dakota (Region 2) appear to have few oil and gas reserves. In 1997, there were no producing wells in Pennington County, where the only area of high development potential is in T2N R17E (USDI Bureau of Land Management 1997) in which there are no known *A. barrii* occurrences. Information for developments

in other counties is less current. In Fall River County, most of the drilling has been in the western part of the county in Ranges 1 through 4 where there are no known occurrences (USDI Bureau of Land Management 1989a). In Custer County, drilling has been limited to a relatively small area and has been most successful in T6S R2E (Black Hills Meridian or 6th Principal Meridian), where again there are no known *A. barrii* occurrences (USDI Bureau of Land Management 1989b). However, this situation may change if lower production wells become more profitable.

Badlands are frequently used for ORV recreation. Dingman (2005) reports that recreational 4x4 use has detrimentally affected several known *Astragalus barrii* populations on land managed by the Bureau of Land Management and the USDA Forest Service in southwestern South Dakota and eastern Wyoming. This is a documented threat to a least one *A. barrii* population in Region 2. In Region 2, the Railroad Buttes area in the Buffalo Gap National Grassland (occurrence SD-5 in **Table 1**) is subject to extensive ORV use (Muenchau et al. 1991a, 1991b). Few *A. barrii* remained where well-used vehicle trails travel through the colonies, and there was “obvious destruction of portions of the colonies observed” (Muenchau 1991a, 1991b). Also on the Buffalo Gap National Grassland, plants are not observed within vehicle tracks although they grow on either side of them (Kostel personal communication 2004). Tracks and roads may also disrupt the natural sediment flow from the top of the buttes to the outwash plains at their base. Since *A. barrii* seed has been observed to frequently follow watercourses and germinate in the sediments, long-term population sustainability may be impacted by disruption of flow in high vehicle-use areas (Dingman personal communication 2004).

Other recreational uses, such as hiking, trapping, and big-game hunting, have not been reported as being threats to this species, but, as for all activities, if the intensity or area of use increases these impacts on the populations will increase. The human population is especially likely to grow in areas with coal bed methane development (Bales 2002). By default, population growth results in a corresponding increase in the urban sphere of influence. The urban sphere of influence includes impacts from recreational activities, from activities such as firewood cutting, and also includes management decisions being shaped by urban concerns in the areas at the edge of federal land and populated areas (urban-wildland interface). Land exchanges between public lands managed by federal agencies and the private sector may pose a threat to some *Astragalus barrii* occurrences (see Population trend

section). Land exchanges that result in consolidation of holdings help to reduce management costs related to boundary management, and land management activities such as fire and invasive species management (Rey 2005). Land exchanges also provide opportunities for community and economic expansion as lands suited for commercial and residential use are moved into the private sector (Rey 2005). Land exchanges have the potential to reduce the amount of habitat available to *A. barrii*. In Region 2, it appears is less likely that *A. barrii* occurrences will be directly impacted because *A. barrii* is designated a sensitive species by the Regional Forester and “the Forest Service strives to achieve a balance between land acquisitions and conveyances to meet the purposes of the National Forest System and the strategic goals of the Forest Service, as well as serving community and economic needs of local governments, State and other non-Federal entities” (Rey 2005).

Livestock grazing is one of the major land uses on public and private lands throughout the range of *Astragalus barrii*. Since most populations of this species occur on marginal rangeland with sparse forage and no water, the plants are likely to receive relatively little use by grazing animals. This is especially true for the populations on steep slopes that would be less accessible to livestock. Trampling and use could be a problem if animals are herded through occupied habitat or induced to use these habitats through the placement of salt blocks or water tanks. Although direct impacts from trampling by native and domestic ungulates have not been documented, they may significantly contribute to erosion of the highly erodible soils. *Astragalus barrii* occurs on active grazing allotments within Region 2. On the Thunder Basin National Grassland, Region 2 approximately 75 percent of occurrences are on active cattle grazing allotments, and one (occurrence WY-13 in **Table 1**) is in a cattle and sheep allotment. Specifically, occurrences WY-11, WY-19, WY-20, WY-25, WY-33, WY-37, WY-38, WY-39 are on active allotments while occurrences WY-12 and WY-22 are not currently in livestock allotments (Staton personal communication 2004). On the Buffalo Gap National Grassland, Region 2, some *A. barrii* occurrences are in cattle allotments, one occurrence is in a sheep allotment (occurrence SD-10 in **Table 1**), and one occurs on an active bison grazing allotment (occurrence SD-24 in **Table 1**). The differences between the impacts of bison (*Bison bison*) and cattle (*Bos taurus*) on *A. barrii* are not known.

Historically, bison roamed throughout badland territory (Bailey 1995), but their specific numbers and use of *Astragalus barrii* habitat type are not known. It seems that bison were likely to have at least

occasionally passed through areas occupied by *A. barrii* in transit between grasslands. Since both species are large bovine ungulates, cattle (*Bos taurus*) may be considered as having replaced bison (*Bison bison*). However, cattle have not provided a simple substitute. Bison utilize different species of plants than cattle and, very importantly, exhibit different foraging and social behavior leading to different types of disturbance patterns (Peden et al. 1974, Jones et al. 1983, Plumb and Dodd 1993). For example, compared to free-roaming bison, livestock grazing at a specific site is typically of longer duration, with a larger number of individual grazers per unit area, and also cattle do not create an environment that is as spatially or temporally diverse as bison generate (Laurenroth and Milchunas 1995, Benedict et al. 1996, Ostlie et al. 1997). This latter observation leads to speculation that bison may have been significant in maintaining the vegetation mosaic of the region. The Audubon's bighorn sheep (*Orvis canadensis audubonii*) was also a native to the badland habitat but is now extinct (Ode 1987). Now the pronghorn (*Antilocapra americana*) is the most abundant large mammal native to the area (Bailey 1995). One other fundamental difference between bison and cattle is in how they may interact with other species of wildlife and exert pressure on vegetation. Pronghorn and bison are complementary in their grazing habits whereas cattle and pronghorn have some of the same preferences (Mack and Thompson 1982). Wyoming, with Montana a distant second, has the largest populations of pronghorn in the United States (Ulrich 1990).

There might be an opportunity to study the influence of large undomesticated mammals within *Astragalus barrii* habitat in Badlands National Park, where bison and Rocky Mountain bighorn sheep (*Orvis canadensis*) have been introduced (Berger and Cunningham 1995, Bourassa 2001). Another opportunity for a comparative bison-cattle study may be on the Buffalo Gap National Grassland in Region 2, where some allotments are open to bison (for example occurrence SD-24 in **Table 1**), rather than cattle. However, the differences between bison and domesticated cattle may not be so great in a ranching situation if bison are herded and thus prevented from exhibiting natural behavior.

When trying to compare the potential impacts from different mammalian herbivores, one might speculate that sheep can have the greatest impact on *Astragalus barrii*. Sheep may use *A. barrii* in preference to other plant species (Vogel and Van Dyne 1966), graze vegetation particularly close to the

ground surface (Berg et al 1997), and indirectly affect bee pollinator abundance (see Community ecology section). Outside of Region 2, some occurrences, (such as MT-27 in **Table 1**) have been reported to experience obvious use by livestock, but the mammalian species was not identified.

Since *Astragalus barrii* occurs within the range of black-tailed prairie dogs (*Cynomys ludovicianus*), the latter might be expected to impact *A. barrii* occurrences through herbivory and disturbance (Uresk 1984, Whicker and Detling 1988). However, Dingman (2005) reports that natural expansion of prairie dog towns is unlikely to substantially impact the persistence of established *A. barrii* populations, at least in Badlands National Park. The loamy substrates and gentle slopes that are attractive to prairie dogs are generally not occupied by *A. barrii*, and the occurrence of prairie dogs and *A. barrii* appear to be mutually exclusive (Dingman 2005).

The competitive ability of *Astragalus barrii* is likely to be low considering the habitat to which it is adapted. Therefore, invasive weeds pose a threat. Habitat is likely to be lost by the spread of the non-natives, yellow sweetclover (*Melilotus officinalis*), bulbous bluegrass (*Poa bulbosa*), and blue mustard (*Chorispora tenella*) in Wyoming (Heidel and Fertig 2003). A non-native mustard, *Malcolmia africana*, is beginning to invade fine-textured slopes of Powder River County in Montana (Heidel et al. 2002). Invasive noxious weed species as defined by the Wyoming Weed and Pest Council (undated) do not seem to have been specifically reported at any of the recorded occurrences (Wyoming Natural Diversity Database 2003). Cheatgrass (*Bromus tectorum*) invasion is particularly perceived as a threat to some populations on the Thunder Basin National Grassland Region 2 and to those in South Dakota (Ode personal communication 2003, Dingman personal communication 2004, Proctor personal communication 2004). Livestock and recreation activities, such as hiking and ORVs, can contribute to the spread of weed seed (Sheley and Petroff 1999, Belsky and Gelbard 2000). Roads are also conduits that facilitate the spread of weeds (Gelbard and Belnap 2003). Weeds often colonize rail tracks, which is likely primarily due the disturbance that tracks continually experience. However, railway trains may also act as weed seed vectors. Schassberger (1990) suggested that natural succession processes that close the canopy over *A. barrii* might result in population declines. As well as natural succession, many areas in the Great Plains have experienced colonization by non-native grass species over the last century (Christian

and Wilson 1999, Heidinga and Wilson 2002). These species are also likely to increase canopy cover within *A. barrii* habitat.

Some weed species, especially grasses that increase the annual amount of accumulated litter, can also alter the frequency with which a site will experience fire. The expansion of invasive annual grasses, such as cheatgrass (*Bromus tectorum*), has decreased fire return intervals (that is, increased fire frequency) in many areas in the western United States, sometimes to beyond the point where native shrubs can recover (D'Antonio and Vitousek 1992). The importance of fire to the life cycle of *Astragalus barrii* is not known, but the low fuel loads of the badlands suggest that its habitat was historically only infrequently exposed to fire (see Community ecology section). Increased fire frequency, as a result of increasing encroachment of annual grasses, may therefore be a threat to some *A. barrii* occurrences. Unintentional exposure of *A. barrii* habitat during prescribed burns on an adjacent areas needs to be avoided (Dingman 2005). The consequence of fire suppression and fire itself on the *A. barrii* life cycle needs further evaluation.

As well as threats associated (directly or indirectly) with human activities, there are stochasticities, or uncertainties, that can only be minimized by having a large number of sustainable populations (Frankel et al. 1995). These stochasticities, which are typically addressed in population viability analysis, include elements of environmental stochasticity, demographic stochasticity, genetic stochasticity, and natural catastrophes (Shaffer 1981).

Variation in precipitation is an example of specific environmental stochasticity that is likely to directly affect the survival and reproductive success of *Astragalus barrii*. Variable populations of arthropods (pollinators, herbivores, granivores), rodents, and other wildlife are other examples of environmental stochasticities that can also impact populations of plants (see Community ecology section). Environmental stochasticities also include elements of global climate change, which potentially may impact *A. barrii*. There is a warming trend throughout the range of *A. barrii* (U.S. Environmental Protection Agency 1997, 1998a, 1998b). Based on projections made by the Intergovernmental Panel on Climate Change and results from the United Kingdom Hadley Centre's climate model (HadCM2), temperatures in Wyoming could increase by an average 4 °F (2.2 °C) in spring and fall, 5 °F (2.8 °C) in summer, and 6 °F (3.4 °C) in winter by 2100 (U.S. Environmental Protection Agency 1998a). Based on the same HadCM2

model, by 2100 temperatures in Montana could increase by about 4 °F (2.2 °C) in spring and summer and 5 °F (2.8 °C) in fall and winter (U.S. Environmental Protection Agency 1997) and in South Dakota, temperatures could increase by 3 °F (1.7 °C) in spring and summer and 4 °F (2.2 °C) in fall and winter (U.S. Environmental Protection Agency 1998b). A future drying trend is predicted for Wyoming (U.S. Environmental Protection Agency 1998a) whereas a slight to moderate increase in total precipitation is predicted for Montana and South Dakota in the future (U.S. Environmental Protection Agency 1997, 1998b). The consensus seems to be that weather will become more extreme in the region. That is, the amount of precipitation on extreme wet or snowy days in winter is likely to increase, and the frequency of extreme hot days in summer will also increase because of the general warming trend. This means that the frequency with which 2 inches of rain fall at one time may increase (U.S. Environmental Protection Agency 1997). This would increase the rate and extent of soil erosion throughout the range of *A. barrii* making it very susceptible to a physical loss of habitat.

It is not clear how global climate change may directly affect *Astragalus barrii*. Schassberger (1990) described heavy losses of plants in Montana occurrences in 1989 after drought in 1987 and 1988 (for example occurrence MT-39 in **Table 1**). She also noted that the populations in the more shaded sites of the Custer National Forest that had a higher percentage of canopy cover and ground litter were less affected by the drought, possibly because of the lower evapotranspiration demand (see Demography section). From these observations, Schassberger (1990) speculated that a change toward a warmer and drier climate would negatively affect *A. barrii*, but those populations in more moist and somewhat atypical sites may be able to thrive. The impact of a warmer climate with unreliable but higher rainfall is difficult to predict. Because *A. barrii* is apparently adapted to harsh conditions, an optimistic scenario is that even if the current sites become too inhospitable, *A. barrii* will be able to colonize sites that have become uninhabitable for other plant species. The caveat of this scenario is that substrate conditions, such as pH (see Habitat section), may restrict *A. barrii* from colonizing any additional habitat. In addition, since *A. barrii* might have poor seed dispersal capabilities, colonization of new suitable habitat may be severely limited (see Demography section).

Demographic stochasticity refers to chance events independent of the environment that affect the reproductive success and survival of individuals. For example, individuals will vary intrinsically with respect

to the number of progeny they can produce. Where occurrences of this species are small, perhaps less than 50 individuals, demographic stochasticity is likely most important (Pollard 1966, Keiding 1975). In very small populations, individuals have a proportionally more important influence on survival of the whole population. If the mature plant is most vital for long-term population sustainability, any event that caused mass extermination of mature plants would likely be injurious to the species. However, a robust soil seed bank may mitigate such adverse consequences. The size of the soil seed bank and seed longevity, both as yet unknown, directly relates to the ability of *Astragalus barrii* to tolerate mass disturbance of adult individuals (see Reproductive biology and autecology and Demography sections).

Genetic stochasticity is associated with random changes, such as inbreeding and founder effects, in the genetic structure of populations. No studies have been undertaken to determine the genetic structure of *Astragalus barrii* populations either on a range-wide or local level. There appear to be several very large populations of *A. barrii* as well as smaller populations. From a genetic perspective, natural populations often behave as if they were smaller than a direct count of individuals would suggest (Barrett and Kohn 1991). Therefore without genetic evaluation, it is essentially impossible to specifically comment on the genetic vulnerability or the minimum size of a sustainable *A. barrii* population. Although not invariably, locally endemic species, including some *Astragalus* species, tend to exhibit reduced levels of polymorphism (Karron 1991, Gitzendanner and Soltis 2000). If there is an absence of appreciable cross-pollination, the short dispersal distances suggest that widely spaced populations may be genetically isolated (see Reproductive biology and autecology section). However, Gitzendanner and Soltis (2000) emphasized that considering that rare species lack genetic variation is an overgeneralization and that each species must be treated as a unique entity. If *A. barrii* is predominately self-pollinated and there is little genetic exchange among the occurrences, then although there may be considerable genetic variation between populations, there may be little variation within populations. There are several instances where rare species of *Astragalus* show significant genetic differences between populations (Karron et al. 1988, Lavin and Marriott 1997).

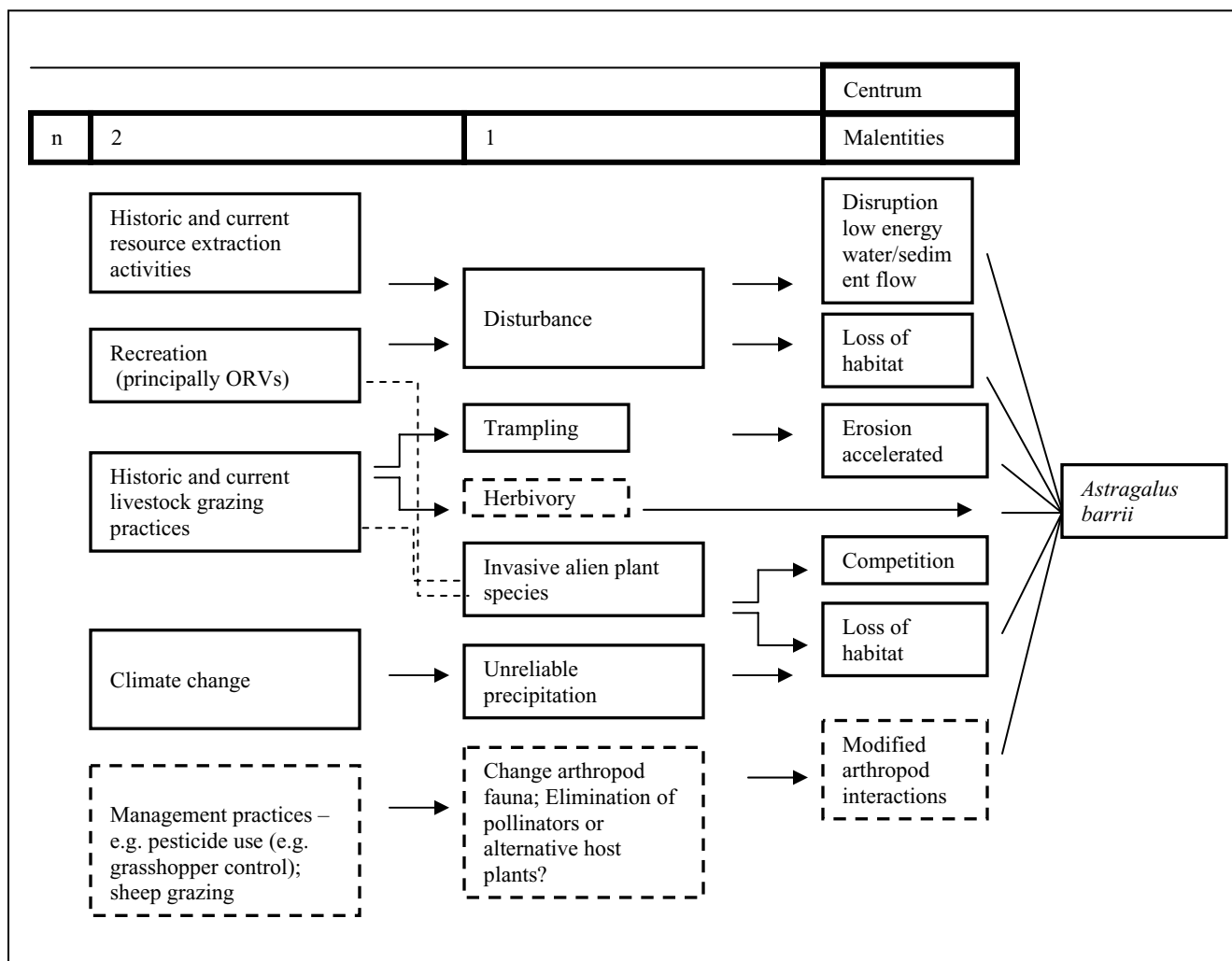
The envirogram of **Figure 8** is constructed to outline some of the factors, including threats that may negatively impact *Astragalus barrii*. There is a lack of direct studies on this species that leads to stretching

the significance of observations and forming opinions from inference rather than fact. Inferences need to be tested or may otherwise lead to erroneous conclusions. Without data from direct studies, the information available needs to be thoroughly evaluated before being used to predict responses to management decisions. At the current time malentities and threats tend to be site-specific. Disturbance is included in the envirogram, but the type and levels that are actually deleterious to long-term sustainability need to be defined. Disturbance can be of two types: direct impacts and the consequences of the initial disturbance. Direct trampling by hikers, large mammals, and off road vehicle traffic can physically damage the plants. Disturbance also contributes to extensive soil erosion and opens areas to invasion by weed species that may eventually result in loss of habitat. Invasive plant species directly compete for resources as well as possibly secreting allelopathic substances into the soil (Sheley and Petroff 1999, Inderjit 2005). A significant consideration, indicated by a dotted line in the envirogram, is the contribution that ORVs and large mammals make to the spread of weed species. Some weed seeds are spread on tires and fur and also through the digestive tracts of animals (Sheley and Petroff 1999). The impacts of potential colonization by invasive plant species that will be exacerbated by anthropogenic disturbances and possible climate change should not be underestimated in any area. Threats associated with herbivory by livestock and native ungulates have been included in a dotted box because at current levels the visible impacts are few. It is not clear that pollinators are important to *A. barrii*. However, if the species is cross-pollinated, pollinator loss or change in their species composition is a potential threat. The suite of arthropod species may alter in response to climate change but also as a consequence of some management practices. For example, some pesticides are very detrimental to bees (Kevan 1975, Larmer 1997). In addition, sheep grazing can destroy wild bee nests (Sugden 1985; see Community ecology section).

In summary, the threats to *Astragalus barrii*, including those concerned with global climate change, are likely largely dependent upon the extent and intensity of the activity. However, the emphasis is “current levels.” Even if the intensity of a threat remains the same, an increase in its area of impact will eventually have negative consequences.

### ***Conservation Status of Astragalus barrii in Region 2***

There is no evidence that the distribution or abundance of *Astragalus barrii* is significantly



**Figure 8.** Envirogram outlining the malentities and threats to *Astragalus barrii* (also see Community ecology section). The dashed line indicates malentities or their causes that are unconfirmed.

changing throughout its range on National Forest System lands although some historical occurrences have not been relocated and some populations have been lost to anthropogenic actions (see Population trend section). The large size of some of the populations, such as those around Railroad Buttes and in the Scenic Basin on the Buffalo Gap National Grassland, Region 2 in South Dakota (occurrences SD-5 and SD-6 in [Table 1](#)) and along the Powder River Breaks in Wyoming (occurrence WY-32 in [Table 1](#)) suggest that *A. barrii* is secure in the short term. On National Forest System lands in Region 2, the potential for loss of habitat does not appear to be of substantial concern in the short term. However, this situation must be evaluated periodically in the light of resource development in the Powder River Basin and recreation development on the Buffalo Gap National Grassland.

Many areas where *Astragalus barrii* occurs on the Buffalo Gap National Grassland are managed with an emphasis on “dispersed recreational activities”, such as big-game hunting, upland game hunting, waterfowl hunting, wildlife viewing, rockhounding, mountain biking, hiking, fishing, and camping (USDA Forest Service 2001a). Currently, the main recreational developments on the Buffalo Gap National Grassland are in the areas of the Railroad Buttes OHV Area and French Creek Campground (USDA Forest Service 2001a). A picnic area and trailhead will be developed at the Railroad Buttes OHV Area. The Red Shirt area is recommended for Wilderness designation, and there is a plan for it to “be managed to protect its rugged, unroaded character, and motorized travel will be restricted” (USDA Forest Service 2001a). In this plan, *A. barrii* was specifically mentioned for management

consideration. Known occurrences within the proposed wilderness area include occurrences SD 20, SD-23, and SD-26 (**Table 1**). Occurrence SD-24 (**Table 1**) may be just outside the proposed boundaries. However, and not withstanding the proposed wilderness designation, trailheads and trails are scheduled for development in the Red Shirt Area (USDA Forest Service 2001a). These developments will likely attract greater use of the area.

### ***Management of *Astragalus barrii* in Region 2***

#### Implications and potential conservation elements

*Astragalus barrii* was included as being a species of concern in the Final Environmental Impact Statement for the Land and Resource Management Plan of the Thunder Basin National Grassland, Region 2 (USDA Forest Service 2001c). The guidelines for the management of *A. barrii* in this document are of a general nature, and a conservation strategy for *A. barrii* has not yet been prepared (Byer et al. 2000). There are no rigorous experimental data on the response of this taxon to most management actions. If sustainability of *A. barrii* relies on relatively long-lived mature individuals (see Demography section), management practices that increase either the frequency or intensity of natural perturbations, or provide additional stresses may significantly negatively impact population viability (Grime 2001, García and Zamora 2003).

The possibility of substantial habitat destruction in some parts of the *Astragalus barrii* range, notably the Powder River Basin, indicates that less disturbed sites, such as those on National Forest System lands in South Dakota, will have considerable importance for long-term conservation of the taxon. Threats from coal bed methane development appear to be low on land managed by Region 2 in South Dakota (USDA Forest Service 2001a). In addition, both the Buffalo Gap and Thunder Basin national grasslands have some standard guidelines that, if followed, will substantially reduce development impacts. For example, rig stacking and storage of equipment not being used is prohibited (USDA Forest Service 2001a, USDA Forest Service 2001b). In addition, special-use and single-use roads associated with oil and gas lease development should be obliterated or rehabilitated within one year from the end of their use period, unless a documented decision is made to keep the road for other management needs (USDA Forest Service 2001a, USDA Forest Service 2001b). The potential for mandatory rehabilitation of roads associated with oil and gas development

suggests that seed from existing local populations of *A. barrii* could be collected for use in a restoration project. The Nebraska Statewide Arboretum has experience in growing *A. barrii* (Locklear undated). Transplantation may also be an option. Small plants of *A. barrii* were successfully transplanted into both a soil mix and into the ground (Barr 1951). The fact that Barr (1951) observed the transplanted individuals increased in number by self-sowing is particularly encouraging when considering a restoration effort for *A. barrii*. It needs to be noted that it is important to use seed or plants from local *A. barrii* occurrences in a restoration effort since genetic diversity may exist between populations (see Reproductive biology and autecology section). If *A. barrii* is cross-pollinated, introduction of genetic material from *A. barrii* plants adapted to areas outside of the restoration area may result in existing *A. barrii* populations experiencing outbreeding depression. Outbreeding depression may occur when local adaptations are disrupted after non-local genotypes are introduced (Waser and Price 1989).

In 1993, Schmoller proposed that *Astragalus barrii* might actually require disturbance. This premise was largely based on *A. barrii* frequently being found in areas that experience moderate soil erosion and sediment deposition. Additional features of this habitat, which may influence *A. barrii* to grow in this niche, are water availability and low competition from other plant species. It has not been found in areas with high erosion. An illustrative measure of erosion, which graphically describes the type of environment very well, is to use the length of exposed root of perennial plant taxa. *Astragalus barrii* was described as being absent when the root of *Eriogonum pauciflorum* was exposed 6 cm (2.4 inches [6.1 cm]; Schmoller 1993). The colonization of road cuts by *A. barrii* and its apparent persistence in lightly disturbed sites also suggests that it has tolerance to periodic disturbance. However, it is important to note that there is little information on which to base predictions as to its response to specific disturbance types or levels. The time of year, as well as the frequency of the disturbance might be important (see Community ecology section). A fundamental gap in knowledge is that it is not known how disturbed areas are re-colonized or whether plants are able to persist at disturbed sites. Protection of small plants by dead parent (nurse) individuals may be important. Observations made by Schmoller (1993) suggested that *A. barrii* was not adversely impacted by the levels of grazing, by either domestic or native ungulates, on the Buffalo Gap National Grassland at that time. Stocking rate and accessibility to alternative range are likely very important.

*Astragalus barrii* does not grow in areas with high vegetation cover, and invasive weeds may contribute to loss of habitat. However, herbicides used to kill dicot (forb) weed species are most likely equally lethal to *A. barrii*. Drift from herbicides used in right-of-way maintenance may pose a threat to occurrences near highways, roads, and railway lines. The need to control invasive species may not be limited to noxious weeds. Heidel et al. (2002) recommended that seeding of sweetclover (*Melilotus* spp.) should be avoided in revegetation efforts or road plantings near this species' habitat in Montana. In addition, the application of herbicides and pesticides must consider the long-term effects not only on *A. barrii* but also on mutualistic species such as pollinators (Bond 1995, Kevan 1975). Monitoring studies that are planned on the Thunder Basin and Buffalo Gap National Grassland will help elucidate some of the biology and ecological requirements of this taxon (Proctor personal communication 2004, Burkhart personal communication 2004).

*Astragalus barrii* individuals tend to occur in small patches within extensive populations. This concentration in specific areas may increase the vulnerability of the species to environmental and genetic stochasticities and to development projects. Some of the populations on National Forest System lands are very large and may be considered as being most important. However, there are also smaller populations, and the value of small populations in conservation should not be underestimated (Karron et al. 1988). When considering which populations to protect, it is important to remember that rare species often exhibit genetic differences between populations (see Threats section). Even though small populations are often considered genetically depauperate as a result of changes in gene frequencies due to inbreeding or founder effects (Menges 1991), Karron et al. (1988) demonstrated that alleles that were absent in larger populations were only found in a small population of *A. osterhoutii*. Therefore, in order to conserve genetic variability, in the absence of genetic data, it is likely most important to conserve as many populations as possible in as large a geographic area as possible and to remember that a "larger" population is not automatically "better".

At the fine-scale, the distribution of *Astragalus barrii* is most likely strongly influenced by microhabitat conditions (Dingman 2005; see Habitat section). The patchy distribution may also be a function of poor seed dispersal. At a coarser level, habitat fragmentation caused primarily by human activities over the last century may also contribute to the uneven distribution of *A. barrii*. Considerable loss and fragmentation of

habitat has occurred due to urban expansion, resource extraction activities, and recreational use (Forrest et al. 2004).

#### Tools and practices

Inventory and monitoring are important tools in sensitive species management. Inventory provides information about the geographic range and abundance of the species while monitoring can demonstrate if management practices are effective. Systematic surveys were made on the Buffalo Gap National Grassland (Region 2) for *Astragalus barrii* in 1991 (Muenchau et al. 1991a, 1991b, Schmoller 1993), and in 1993 (Hoy et al. 1993b, Schmoller 1993). The surveys of Muenchau et al. (1991a) led to transects being established in 1993 in the Railroad Buttes area for monitoring purposes (Hoy et al. 1993b, 1993c). It is not clear if the transects established in the Scenic Basin area were permanently marked (Schmoller 1993). However, no further studies were made after 1993. In the Spring Creek Unit of the Thunder Basin National Grassland, a survey for *A. barrii* was made in 2003. It was primarily designed to familiarize USFS personnel with the species and appropriate survey techniques. The surveys were developed using photo-interpretation and ground-truthing (Heidel 2004).

Further documented inventory and monitoring activities are needed for *Astragalus barrii*. Monitoring activities are particularly important because there is little information on population structure and the persistence or colonization rate of individuals. It is also very important in monitoring and inventory surveys to standardize collection procedures so that information can be compared across years. A statistician is a very valuable team member when designing a plant survey where quantitative data will be analyzed.

A very significant consideration in *Astragalus barrii* management is that it is important that plants be flowering during surveys. The vegetative similarity between sympatric *Astragalus* species can lead to misidentification of the species or the over-estimation of its abundance (see Distribution and abundance section). This similarity also precludes accepting remote surveys, such as with binocular scans of adjacent lands, as being confirmed sightings.

#### Species inventory

*Astragalus barrii* needs to be periodically inventoried in order to know its status. The current field survey forms for endangered, threatened, or sensitive

plant species used by the South Dakota Natural Heritage Program, the Wyoming Natural Diversity Database (see **References** section for internet addresses), and the Nebraska National Forest all request the collection of data that is appropriate for inventory purposes. The number of individuals and the area they occupy are important data for occurrence comparison. The easiest way to describe populations over a large area may be to count patches, making note of their extent, and estimate or count the numbers of individuals within patches. A statement like “many individuals” is subjective, and on the field survey form an estimation of the number observed is most helpful. Collecting information on the dates of flowering, the fractions of the population that are flowering or with fruit, and the presence of seedlings is also important for assessing the vigor and fecundity of a population. Observations on habitat are also very valuable and are customarily recorded during inventory surveys.

In the case of new occurrences, it is especially important to collect a specimen and deposit it in a publicly accessible herbarium. It is important that the collected specimen have both flowers and fruit. However, it might not be prudent to take whole specimens from small populations, and the advisability of collecting a whole specimen needs to be considered on an occurrence-specific basis. Where there are few individuals and thus concern about detrimentally impacting the population, taking a few branches with flowers, pods, and leaves, but not damaging the root, would probably be the most appropriate way to document the occurrence. These parts, defined as a “fragmentary voucher,” need to be deposited in a publicly accessible herbarium. A photograph and description of flower color associated with the fragmentary voucher are also particularly useful. It is useful to bear in mind that some colored photographs fade over time. A close-up colored photograph and an additional wide-angle photograph of an *Astragalus barrii* plant and its habitat retained with the survey record form are additional forms of documentation that are worthwhile for future reference. An expert in the *Orophaca phalanx* may be able to distinguish between vegetative individuals of *A. barrii* and other three-leaved *Astragalus* taxa (Roche personal communication 2005). However, because of the inconspicuous nature of *A. barrii* when vegetative and the similarity between this taxon and sympatric taxa, it is important that surveys be carried out when the plant is flowering (see Non-technical description section).

Several methods have been used to count or estimate individual *Astragalus barrii* plants on parts of

the Buffalo Gap National Grassland. Two methods are described in detail (Hoy et al. 1993c, Schmoller 1993). However, there are many established inventory methods that may be statistically more valid and should be considered before any inventory project is implemented (Cochran 1977, Ludwig and Reynolds 1988, Kent and Coker 1992, USDI Fish and Wildlife Service 2002).

One of the methods, designated here as Method 1, used topographic maps to delineate the occupied habitat using either a Global Positioning System (GPS) or by estimating the area on the ground (Schmoller 1993). Representative population densities were estimated by sampling plot frames (1 x 2 ft; 0.19 m<sup>2</sup>) along a transect line within the boundaries of an area containing *Astragalus barrii* (Schmoller 1993). At regularly-spaced intervals along the transect line, the number of plants that were within the plot frame were counted. There were from 12 to 64 readings (plot frames) per transect. The reason for the different number of plot frames per transect was not given, but it was presumably because the occurrence sites were of different sizes. The variation per frame was, not unexpectedly, high; numbers of plants per frame ranged from 22 to zero. Within occupied habitat, zero was frequently encountered.

The data generated in Method 1 may be analyzed in different ways. In the original paper (Schmoller 1993), the plant density in each plot frame along each transect were averaged. The average plant density along all transects was then averaged and converted to plants per hectare and then to plants per acre. Finally, the number of plants estimated to be per acre was multiplied by the total number of acres projected to contain *Astragalus barrii* (**Table 3a**; Schmoller 1993). The value of the number per square meter per transect was given equal weight in the original analysis. However, because each transect covered a different sized area (for example 9 frames versus 64 frames), they are not directly comparable, and to weight them equally is inappropriate. If, as was the case, one area was particularly dense, then the number of plants per square meter increased disproportionately in the area as a whole (**Table 3a**, **Table 3b**, **Table 3c**, and **Table 3d**). If the total number of plants is divided by the total number of frames, then the number per square meter and thus the total in the population is significantly less, 25 percent less, and is very similar to the number after the unusually high number (outlier) is excluded from the analysis (**Table 3b** and **Table c**). The value remains similarly lower if both the highest and lowest values (outliers) are excluded (**Table 3d**). Excluding outlying

**Table 3a.** Original analysis (Table 3a from Schmoller 1993) and alternative analyses (Tables 3b-3d) for results from the survey described as Method 1. Please see text.

No. of individuals	No. of frames (frame=0.19m <sup>2</sup> )	Individuals				Total in 408 acres
		per frame	per m <sup>2</sup>	per hectare	per acre	
58	30	1.93	10.41	104,051	42,126	17,176,441
85	16	5.31	28.59	285,916	115,756	47,198,195
26	15	1.73	9.33	93,287	37,768	15,399,568
9	40	0.23	1.21	12,109	4,903	1,998,982
15	9	1.67	8.97	89,699	36,315	14,807,277
28	64	0.44	2.35	23,546	9,533	3,886,910
22	48	0.46	2.47	24,667	9,987	4,072,001
43	31	1.39	7.47	74,653	30,224	12,323,476
35	31	1.13	6.08	60,764	24,601	10,030,736
49	17	2.88	15.51	155,127	62,804	25,607,879
9	12	0.75	4.04	40,365	16,342	6,663,275
5	31	0.16	0.87	8,681	3,514	1,432,962
17	25	0.68	3.66	36,597	14,817	6,041,369
Average		1.44	7.77	77,651	31,438	12,818,390

**Table 3b.** Analysis giving each frame equal weight in the analysis. Result is that there are 25 percent fewer individuals than in the original estimate.

No. of individuals	No. of frames (frame=0.19m <sup>2</sup> )	Individuals				Total in 408 acres
		per frame	per m <sup>2</sup>	per hectare	per acre	
401	369	1.09	5.85	58,487	23,679	9,654,826

**Table 3c.** Analysis that excludes the most and least dense populations. Result is that there are 16 percent fewer individuals than in the original estimate.

No. of individuals	No. of frames (frame=0.19m <sup>2</sup> )	Individuals				Total in 408 acres
		per frame	per m <sup>2</sup>	per hectare	per acre	
58	30	1.93	10.41	104,051	42,126	17,176,441
26	15	1.73	9.33	93,287	37,768	15,399,568
9	40	0.23	1.21	12,109	4,903	1,998,982
15	9	1.67	8.97	89,699	36,315	14,807,277
28	64	0.44	2.35	23,546	9,533	3,886,910
22	48	0.46	2.47	24,667	9,987	4,072,001
43	31	1.39	7.47	74,653	30,224	12,323,476
35	31	1.13	6.08	60,764	24,601	10,030,736
49	17	2.88	15.51	155,127	62,804	25,607,879
9	12	0.75	4.04	40,365	16,342	6,663,275
5	31	0.16	0.87	8,681	3,514	1,432,962
17	25	0.68	3.66	36,597	14,817	6,041,369
		1.12	6.03	60,296	24,411	9,953,406

**Table 3d.** Analysis that excludes the most dense population from the analysis. Result is that there are 22 percent fewer individuals than in the original estimate.

No. of individuals	No. of frames (frame=0.19m <sup>2</sup> )	Individuals				Total in 408 acres
		per frame	per m <sup>2</sup>	per hectare	per acre	
58	30	1.93	10.41	104,051	42,126	17,176,441
26	15	1.73	9.33	93,287	37,768	15,399,568
9	40	0.23	1.21	12,109	4,903	1,998,982
15	9	1.67	8.97	89,699	36,315	14,807,277
28	64	0.44	2.35	23,546	9,533	3,886,910
22	48	0.46	2.47	24,667	9,987	4,072,001
43	31	1.39	7.47	74,653	30,224	12,323,476
35	31	1.13	6.08	60,764	24,601	10,030,736
49	17	2.88	15.51	155,127	62,804	25,607,879
9	12	0.75	4.04	40,365	16,342	6,663,275
17	25	0.68	3.66	36,597	14,817	6,041,369
		1.21	6.50	64,988	26,311	10,727,992

values that fall outside two standard deviations of the mean has been recommended to avoid inappropriate weighting (Steel and Torrie 1960, Cochran 1977).

Another method, Method 2, used a frequency-nested design to estimate abundance (Hoy et al. 1993c). At each of five sites, two permanently marked 60-m (198.6-foot) transects were established giving a total of ten transects. Ten quadrats, each one square meter, were randomly placed along each transect. The frequency with which the plants occurred in each of the quadrats was recorded. Unlike Method 1, each quadrat was treated as an independent unit for some analyses. *Astragalus barrii* was observed to be a dominant species at some times during the growing season. Only one year (1993) of data was collected, and it would be very interesting to make similar studies now that over a decade has passed.

Reproducing these surveys exactly or directly comparing the results is difficult with the information available. In order to use information, years, and sometimes several decades, after a survey is completed, it is very important that full details of the methods used be described at the time when survey is conducted. Critically defining the methods and appropriate statistical treatment before a survey is conducted is also very important because the method and assumptions of the analysis can lead to large differences in the conclusions that are reached (compare total plant estimates in [Table 3a](#), [Table 3b](#), [Table 3c](#), and [Table 3d](#)).

### *Habitat inventory*

The available information on habitat suggests that it is possible to make a general inventory of areas that have the potential for colonization by *Astragalus barrii*. However, there are no critical studies that relate the abundance or vigor of populations to specific habitat conditions or that indicate the rates or manner of colonization. Therefore, defining the quality of the habitat or the likelihood of colonization may be subject to error. A collaborative effort between several institutions and the USDA Forest Service is being made to model and map habitat for *A. barrii* in Wyoming (Roche personal communication 2005). Studies have recently been made to model habitat characteristics of populations on the Badlands National Park in South Dakota (Dingman 2004, Dingman 2005). When using habitat models, it needs to be remembered that a model developed only for one area cannot be generally applied through the range (see Habitat section). For example, if model development is restricted to occurrences on any specific geological formation, for example the Chadron or Brule formation, then application of the model to populations outside that geological formation could lead to erroneous conclusions. The patchy distribution pattern of *A. barrii* suggests that particular microclimate conditions need to be met in order to support the plants, and that interspecific competition, or rather the lack of it, is very important to its ecology (Dingman 2005; see Habitat and Community ecology sections). In addition, solely relying on models to determine the extent of available potential habitat may be unwise, since

habitat models frequently do not have a high degree of predictive power (Wiser et al. 1998, Boetsch et al. 2003, Dingman 2005).

### *Population monitoring*

The first year of a monitoring or demographic study was reported within species inventory surveys by Muenchau et al. (1991a), Hoy et al. (1993b, 1993c), and Schmoller (1993). The experimental design, statistical analyses, and results of these studies should be reviewed before implementing further monitoring plans (see Species inventory section). Other techniques should also be considered. Non-parametric statistical analysis methods are particularly useful in ecological studies where environmental or other uncontrollable events can ruin the implementation of a conventional parametric design. It is important to consider the means of analysis of the data before collecting it.

Permanent plots are very useful in determining population structure, life history of individual plants, and longevity of individual patches (Goldberg and Turner 1986, Johnson-Groh and Lee 2002). Lesica (1987) discussed a method for monitoring non-rhizomatous, perennial plant species using permanent belt transects. He also described life stage or size classes and reproductive classes that might be appropriate to consider for *Astragalus barrii*. He applied the technique to *A. scaphoides*, which grows at moderate to low densities. Following Lesica's guidelines, Rittenhouse and Rosentreter (1994) established similar permanent transects for making demographic studies and monitoring *A. amblytropis*, another perennial *Astragalus* growing on shale but endemic to east-central Idaho. They also described a modified transect method that they used in the second year of study to increase the sample size. The latter method marked each plant individually within 1 m (approximately 3 feet) of the transect line. The size classes, for example based on the number of leaves or number of stems, need to be assigned after intense observations on the plants. It is likely that monitoring would start after a first year is used to study a taxon over its entire growing season.

Typically, permanent plots may not be suitable if individuals are short-lived and/or the goal is to monitor sub-samples in order to detect changes in a larger population over a long time period. This is because using permanent monitoring plots may cause problems associated with spatial auto-correlation (Goldsmith 1991). To minimize such problems, monitoring protocols for species with a spatially aggregated, or

patchy, distribution have been described by Elzinga et al. (1998) and Goldsmith (1991).

### *Habitat monitoring*

Habitat monitoring of plant occurrences needs to be associated with population monitoring protocols. Recording habitat descriptions during population monitoring activities permit evaluating the relationship between environmental conditions and abundance over the long-term. Developing a description of the climate in the areas where *Astragalus barrii* occurs may also help in interpreting any trends that are detected in its abundance. Conditions several years prior to the onset of a decrease or increase in population size may be more important than conditions existing during the year the change is observed. Current land use designation and evidence of land use activities are important to include with monitoring data. For example, where possible it needs to be noted if populations are on an active grazing allotment even though no use by livestock is observed at the time. Because there is an understanding of what areas represent potential habitat, it may be possible to monitor total habitat conditions to a limited extent. For example, changes in vegetative cover, presence of invasive plant species, and erosion patterns could be observed, and remedial actions could be taken in apparently suitable but unoccupied habitat. This might be especially appropriate in areas that are relatively near known populations.

Photographic documentation is very useful in visualizing coarse-scale vegetation changes over time and is increasingly used to augment monitoring records. The use of photopoints and photoplots is advocated in monitoring the habitat of *Astragalus barrii*. However, photographic documentation is not an effective replacement for written observations and quantitative monitoring procedures. Photopoints are collections of photographs of the same frame that have been retaken from the same position over some given time period. Photoplots are usually relatively close-up photographs showing a birds-eye-view of the monitoring plot. In both cases, a rebar or some other permanent marker should be placed to mark the location where the photographer stands, and compass directions and field-of-view details must be recorded to make sure the photograph can be accurately re-taken. Even though digital copies are convenient and easy to store, many museums and researchers suggest storing additional slides and hardcopies as in 50 years, or perhaps even 5 years, the technology to read the digital media that is currently used may no longer be available. For the same

reason, another suggestion is that data be transferred to new formats periodically so that the information is not lost. Having black and white photographs as backups to color is also recommended since color often tends to fade after several years.

#### *Population or habitat management approaches*

There have been no systematic monitoring programs for populations in protected areas versus those in areas with high disturbance levels. Therefore, the benefits of protection cannot be critically evaluated.

Dingman (2005) considers that one of the primary risks posed to *Astragalus barrii* in Badlands National Park and other areas of the Northern Great Plains is the implementation of prescribed fire. Dingman (2005) suggested that proposed burn units that include *A. barrii* habitat be surveyed for plants in the May of the growing season before the burn plan is completed. She suggests that where populations are found within areas scheduled to experience prescribed burns, “specific measures should be incorporated into the burn plan to exclude fire from those areas. Care should be used in planning for use of imprecise firing techniques, such as aerial ignition, where populations exist in the burn unit. Additionally, vehicular access should be restricted from the populations” (Dingman 2005). Another management recommendation was to avoid any activity that would contribute to the spread of invasive weed species, particularly annual brome grasses (*Bromus tectorum* and *B. japonicus*) and yellow sweetclover (*Melilotus officinalis*), which can colonize *A. barrii* sites, even to the point of growing within its leafy crown (Dingman 2005). No specific recommendations have been made for chemical weed control of weedy species within *A. barrii* occurrences since annual and biennial weed species are not easily controlled with herbicide and there is a high likelihood that *A. barrii* will be sensitive to applied chemicals (Digman 2005). This is especially true for any herbicide used to control yellow sweetclover (*Melilotus officinalis*), because it is not only a dicot but also a legume. Dingman (2005) also suggested that activities that cause high intensities of disturbance, such as recreational ORV use, be prohibited in areas in which *A. barrii* occurs. Similarly, prolonged backcountry use, such as field camps used by researchers or hunters, should be sited to avoid *A. barrii* occurrences since concentrated trampling may be beyond the tolerance of *A. barrii* plants (Dingman 2005). No consequences of implementing such management recommendations have been reported.

### ***Information Needs***

At the present time, *Astragalus barrii* seems to be a naturally uncommon species restricted to specific soil and community types within a limited geographic range. It does not appear to have substantially declined in range or abundance over the last few decades, although one cannot say with certainty that it has not experienced a decline in the last century. Further inventory surveys need to be made. Monitoring of pre-existing sites is essential in order to understand the implications of existing and new management practices. Where management practices are likely to change, inventory needs to be taken to collect baseline data, and periodic monitoring conducted after the new policy is initiated. In particular, colonies in high disturbance areas, for example areas that receive ORV use or experience resource development, need to be monitored because tolerance data are not currently available to determine the long-term survival of plants at disturbed sites. The impacts from accelerated erosion and increased soil compaction may take several decades to become apparent. Therefore, periodic monitoring of existing sites appears to be a primary need.

In addition to monitoring and inventorying this species, there are unanswered questions about its biology and ecology that would influence its management. Habitat information collected for *Astragalus barrii* throughout its range suggests that its habitat requirements are quite complex and that generalizations may lead to misconceptions. A comprehensive study on the edaphic requirements of *A. barrii* may elucidate the reason for its distribution, localized abundance, and overall rarity. The spatial dynamics within populations are also unknown. It may be useful to consider that *A. barrii* is reproductively atypical of others in the *Orophaca* phalanx, in that it appears to produce abundant flowers, and possibly, also abundant fruit. It is currently thought that substrate and vegetative cover are primary factors that limit population size and abundance and that contribute to the variable occurrence sizes. This needs to be confirmed experimentally. The ability of *A. barrii* to tolerate interspecies competition is speculated as being very low. If so, non-native invasive species may pose a significant threat.

Differentiating between whether *Astragalus barrii* plants colonize or persist at sites that have experienced anthropogenic disturbance is an important aspect of the ecology of *A. barrii* and may be central to its management. The observation that most individuals

appear long-lived suggests that persistence in adult form is critically important to the life history of this species. Alternatively, observations that the plant grows in areas such as road cuts suggest that it can relatively rapidly (re)colonize such areas and act as a pioneer species. In this case, additional studies need to be carried out to determine if the size of the soil seed bank or fecundity of nearby populations are of the greater importance to colonization. The rate at which *A. barrii* colonizes potential habitat is unknown, and there may be a substantial difference between re-colonizing an area from a pre-existing soil seed bank rather than colonizing an area through seed dispersal. Soil properties appear important to the ecology of *A. barrii*, and the long-term consequence of anthropogenic disturbance to critical soil properties is unknown.

Understanding the reproductive system and the genetic variability of *Astragalus barrii* would permit the making of biologically informed management decisions for long-term conservation. The extent of genetic variability between *A. barrii* populations is important when considering the potential genetic losses associated with loss of individual populations. If genetic variability exists between populations, establishing colonies using seeds or plants from the impacted populations may conserve genetic resources. The degree to which colonies interact also influences the delineation of discrete occurrences if occurrences are equated with populations (see Distribution and abundance section). The reproductive method also needs to be clarified to appreciate the importance of pollinators. Although comparisons with other rare *astragali* suggest that *A. barrii* might be self-pollinating, this might not be the case. *Astragalus barrii* could even be obligately cross-pollinated. Management practices, for example grazing policies, may need to be modified if specific pollinators are found to be essential for cross-pollination (see

Community ecology section). In addition, prescriptive pesticide applications may need to be reviewed to ensure that the chemicals used to control other species do not affect the specific pollinators of *A. barrii*.

Primary information needs can be summarized thus:

- ❖ More information is needed on the longevity and sustainability of populations, which can be gathered through monitoring studies.
- ❖ More information is needed on the impact of human-caused disturbances, such as vehicle traffic, on the long-term response of individuals and populations, which can be obtained through monitoring studies. This is needed in order to promote proactive steps towards threat mitigation.
- ❖ More information is needed on the habitat requirements, which can be obtained through analysis of existing data and conducting directed ecological surveys.
- ❖ More information is needed on the reproductive and pollination biology of *Astragalus barrii*, which can be obtained through directed field studies. The relationships between the frequency with which individual plants flower, the apparent yearly seed production, and the likely episodic seed germination needs to be determined.
- ❖ Additional inventory on land that has not been surveyed needs to be made so that a comprehensive conservation plan can be formulated.

## DEFINITIONS

**Allopatric** – applied to species that grow in different habitats and do not occur together in nature (Allaby 1992).

**Autogamous** – self-fertilizing.

**Badlands** – “an intricately stream-dissected topography, developed on surfaces with little or no vegetative cover. Underlying material is generally unconsolidated or weakly cemented silt or clay, sometimes with gypsum or halite. Badlands may develop in humid areas if vegetation is removed by overgrazing or other causes” (Bates and Jackson 1984).

**Calcicole** – a plant species confined to, or most frequently found on, alkaline soils. Specifically those soils containing free calcium carbonate (Allaby 1992).

**Calyx** – the outer part of a flower, usually consisting of green, leafy sepals.

**Caudex** - the perennial, often woody, region between the base of the stem and the top of the roots that slowly elongates and is commonly branched.

**Chalcedony** – a cryptocrystalline variety of silica dioxide, or quartz (Bates and Jackson 1984).

**Deciduous** – falling off each season (as leaves); bearing the deciduous parts (as trees).

**Dolabriform** – T-shaped or pick-shaped hairs. “Said of hairs apparently attached in their middle (Harrington and Durrell 1986).

**Dust devil** – see definition of whirlwind.

**Edaphic** – pertaining to the physical, chemical, and biological characteristics of the soil.

**Endemic** – confined to a given region (for example island, mountain range or country) or specific set of environmental conditions (for example gypsum or serpentine soils).

**Erodible** – susceptible to erosion.

**Fire Regime** – description of the patterns of fire occurrences, frequency, size, severity, and sometimes vegetation and fire effects as well, in a given area or ecosystem. A fire regime is a generalization based on fire histories at individual sites. Fire regimes can often be described as cycles because some parts of the histories usually get repeated, and the repetitions can be counted and measured, such as fire return interval. See also Fire Regime Groups (National Wildfire Coordinating Group 2005).

**Fire Regime Groups** – a classification of fire regimes into a discrete number of categories based on frequency and severity. The national, coarse-scale classification of fire regime groups commonly used includes five groups: I - frequent (0-35 years), low severity; II - frequent (0-35 years), stand replacement severity; III - 35-100+ years, mixed severity; IV - 35-100+ years, stand replacement severity; and V - 200+ years, stand replacement severity (National Wildfire Coordinating Group 2005).

**Flavone** – a compound,  $C_{15}H_{10}O_2$ , and the parent substance of a number of important yellow pigments, occurring on the leaves or in the stems and seed capsules of many primroses (after The American Heritage® Dictionary of the English Language. 2000. Fourth Edition. Published by the Houghton Mifflin Company).

**Fragmentation** – in the context of “habitat fragmentation” the word refers to continuous stretches of habitat that become divided into separate fragments by land use practices such as agriculture, housing development, logging, and resource extraction. Eventually, the separate fragments tend to become very small islands isolated from each other by areas that cannot support the original plant and animal communities.

**Genic** – of, having the nature of, or caused by a gene or genes (Guralnik 1982).

**Glycoside** – sugar derivative of a chemical. That is: Any of a group of organic compounds, occurring abundantly in plants, that yield a sugar and one or more non-sugar substances on hydrolysis (The American Heritage® Dictionary of the English Language. 2000. Fourth Edition. Published by the Houghton Mifflin Company).

**Hemicryptophytes** – herbs with perennating buds at soil level, protected by soil itself or by dry, dead portions of the plant (Abercrombie et al. 1973).

**High intensity fires** – those fires having high temperatures that penetrate the soil deeply, thereby severely damaging and often completely destroying all vegetation.

**Holotype** – the single specimen designated as the type of the species by the original author at the time that the species name and description was published.

**Inholding** – any right, title, or interest, held by a non-Federal entity, in or to a tract of land that lies within the boundary of a federally designated area. (43 USC Sec. 2302, 1/19/04; that is: Title 43 - Public lands, Chapter 41 – Federal land transaction facilitation, Sec. 2302 - Definitions. Available online at: <http://uscode.house.gov/download/pls/43C41.txt>).

**Keel** – (of an Astragalus flower) technically two petals, fused along their lower margins and appearing as the keel of a boat.

**Legume** – a one-celled fruit that splits along two sutures or seams (e.g., pea).

**Lepidoptera** – butterflies and moths; insect characterized by having two pairs of large wings, both wings and body covered with scales, and its larva being a caterpillar (Abercrombie et al. 1973).

**Marcrescent** – dry and persistent. That is: withering but not falling off, as a blossom that persists on a twig after flowering (The American Heritage Dictionary of the English Language. 2000. Fourth Edition. Houghton Mifflin Company, Boston, Massachusetts).

**Microbiotic soil crust** – biological communities, also known as cryptogamic, cryptobiotic, microphytic and microfloral soil crusts. These crusts are complex assemblages of one or more species of lichen, bryophyte (moss and liverwort), fungi, algae, cyanobacteria (blue-green algae), or bacteria growing on or just below the soil surface. Microbiotic crusts do not necessarily contain representatives of all the life forms and may appear to be almost monotypic during casual observation.

**Nurse plant** – a plant that benefits the growth of other plants, such as seedlings, through processes such as providing shade, providing protection from herbivory, providing protection from frost, and/or modifying microclimates.

**Pedicel** – the stalk of one flower in a cluster.

**Peduncle** – the stalk of a flower cluster or of a solitary flower.

**Pedunculate** – having a peduncle.

**Persistent** – remaining on the plant; not falling off readily.

**Petiole** – the stalk of a leaf.

**Phalanx** – in North America, the species in the genus *Astragalus* are divided into “phalanxes” (which can be thought of as “sub-genera”) that in turn are divided into sections and sometimes further into sub-sections (Barneby 1964).

**Play** – in the context of an individual “coal-bed methane play”, it refers to a group of strata characterized by similar aspects of methane occurrence (U.S. Geological Survey 2000).

**Polylectic** – applied to bees that visit different species plants for pollen (and nectar) compared to oligolectic that refers to a bee which visits only one, or a few related, plant species for pollen.

**pH** – “A quantitative expression for acidity or alkalinity of a solution, i.e. concentration of hydrogen or hydroxyl ions. Scale ranges from 0 to 14, pH 7 being neutral, less than 7 acid, more than 7 alkaline” (Abercrombie et al. 1973).

**Pubescent** – “Loosely used for covered with hairs; technically with short hairs” (Harrington and Durrell 1986).

**Ranks** – global ranks are assigned by NatureServe scientists or by a designated lead office in the Natural Heritage Network. G3 or S3: “Vulnerable” —Vulnerable globally (G) or within the subnation [state] (S) either “because very rare and local throughout its range, found only in a restricted range (even if abundant at some locations), or because of other factors making it vulnerable to extinction or elimination. Typically 21 to 100 occurrences or between 3,000 and 10,000 individuals.” G2 or S2: “Imperiled” — Imperiled globally (G) or within the subnation [state] (S) because

“of rarity or because of some factor(s) making it very vulnerable to extinction or elimination. Typically 6 to 20 occurrences or few remaining individuals (1,000 to 3,000) or acres (2,000 to 10,000) or linear miles (10 to 50).” For further information see NatureServe online at: <http://www.natureserve.org/explorer/granks.htm>.

**Section** – in North America, the species in the genus *Astragalus* are divided into “phalanxes” (which can be thought of as “sub-genera”) that in turn are divided into sections and sometimes further into sub-sections (Barneby 1964).

**Sympatric** – the occurrence of two species together in the same area (Allaby 1992).

**Whirlwinds and dust devils** – whirlwinds and dust devils, which are small whirlwinds, are rotating columns of air made visible by dust, sand, and debris. They are created when air near the ground surface becomes much warmer than the air above. This creates an instability in which the warm air rises.

**Trifoliate** – having three leaves.

**Topotype** – a specimen of a plant collected from the same locality as the holotype and usually on a different date. A topotype has no formal standing and is sometimes referred to as a locotype.

**Watch (species)** – any species either known to be imperiled and suspected to occur on BLM lands; suspected to be imperiled and documented on BLM lands; or needing further study for other reasons based on the status of species on Bureau of Land Management Lands as defined by the BLM 6840 Manual; designated by the Montana State Office of the BLM in 1996 (<http://fwp.mt.gov/fieldguide/statusCodes.aspx>).

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